BIOLOGY (revised)

Advanced Higher

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National Course specification

Biology (revised) Advanced Higher

COURSE CODE C274 13

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Course structure

This Course has three mandatory Units. The mandatory Units are:

H0AK 13 *Cells and Proteins* (Advanced Higher)
H0AL 13 *Organisms and Evolution* (Advanced Higher)
H0AM 13 *Investigative Biology* (Advanced Higher)

Recommended entry

While entry is at the discretion of the centre, candidates would normally be expected to have attained a National Qualification at SCQF level 6 in Biology, Human Biology, Biotechnology or equivalent.

Progression

This Course or its Units may provide progression to:

- Life science Courses at SCQF level 7 or level 8.

National Course specification: (cont)

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Credit value

The Advanced Higher Course in Biology is allocated 32 SCQF credit points at SCQF level 7*.

**SCQF points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Each of the Units in this Course attracts 8 SCQF credits. Units attracting 8 credits would be 40 hours of programmed learning. This Course includes 8 SCQF credits for 40 additional programmed hours which are not tied to any specific Unit. This may be used for induction, extending the range of learning and teaching approaches, support, consolidation, integration of learning and preparation for Course assessment.

Core Skills

Opportunities to develop aspects of Core Skills are highlighted in the Support Notes of the Unit specifications for this Course.

There is no automatic certification of Core Skills or Core Skill components in this Course.

National Course specification: Course details (cont)

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Rationale

The Advanced Higher Biology Course is based on integrative ideas and unifying principles of modern biological science. It covers key aspects of life science at the molecular scale and extends to aspects of the biology of whole organisms that are among the major driving forces of evolution. In addition, the Advanced Higher Biology Course aims to develop a sound theoretical understanding and practical experience of experimental investigative work in biological science.

The Course provides candidates with the opportunity to develop a deeper understanding of the cell by studying the key roles of proteins within the cell. This understanding of cellular processes is then related to physiological function. At the whole organism scale the Course explores how sexual reproduction and parasitism are major drivers of evolution. This allows candidates to develop a deeper understanding of the mechanism of evolution, the biological consequences of sexual reproduction and the biological inter-relationships involved in parasitism. The Course provides a deeper understanding of laboratory and fieldwork techniques and in carrying out a biological investigation the candidate has the opportunity to produce an extended piece of scientific work.

Throughout the Course there are ample opportunities to develop a systems approach to the study of biological science allowing candidates to integrate their learning and to develop an appreciation of the global dimension to life on Earth and the importance of understanding biological issues in our society. The further development of scientific skills and experience acquired in previous learning will extend candidates' capability to embark on independent investigative work and by designing and carrying out their own investigation candidates will increase their scientific literacy and develop skills for learning, life and work.

National Course specification: Course details (cont)

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Course content

The content of the Advanced Higher Biology Course develops knowledge and understanding, skills of scientific experimentation, investigation and enquiry and skills for learning, life and work. The knowledge and understanding and the skills associated with the Course content should be developed in contexts related to the content and explanatory notes in the tables of the Course specification. The suggested learning activities and approaches provide contexts in which science skills and knowledge and understanding can be developed and are not liable for assessment although they may provide contexts for assessment items. It is not intended that learners should cover all of these suggested learning activities and approaches, rather a selection of these may be used along with other activities and approaches to best suit learners' needs.

Knowledge and understanding

Through study of the biology associated with the content statements and explanatory notes in the following tables, candidates should be able to:

1 Demonstrate knowledge by making accurate statements about and describing the biology of cells, organisms, relationships, processes, systems and cycles.
2 Apply their knowledge to new situations and when interpreting biological information and solving problems.
3 Demonstrate understanding by providing explanations and integrating different areas of knowledge.

Skills of scientific experimentation, investigation and enquiry

Practical work is essential in providing the contexts for the development of science skills. Through practical work candidates develop a deeper understanding of biological knowledge and acquire skills of:

1 Selecting relevant information from texts, tables, charts, keys, graphs and/or diagrams.
2 Presenting information appropriately in a variety of forms, including written summaries, extended writing, tables and/or graphs.
3 Processing information accurately using calculations where appropriate. Calculations to include percentages, averages and/or ratios. Significant figures and units should be used appropriately.
4 Planning and designing experimental procedures to test given hypotheses or to illustrate particular effects. This could include identification of variables, controls and measurements or observations required.
5 Evaluating experimental procedures by commenting on the purpose or approach, the suitability and effectiveness of procedures, the control of variables, the limitations of equipment, possible sources of error and/or suggestions for improvement.

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6 Drawing valid conclusions and giving explanations supported by evidence or justification. Conclusions should include reference to the overall pattern to readings or observations, trends in results or comment on the connection between variables and controls.
7 Making predictions and generalisations based on available evidence.

Skills for learning, life and work

By acquiring the knowledge, understanding and skills involved in the study of Biology, candidates should develop capabilities that will enable them to be successful learners, confident individuals, responsible citizens and effective contributors. By becoming scientifically literate individuals they should be able to communicate scientific knowledge by selecting and presenting relevant information. They should be able to analyse and interpret data to draw conclusions and to make predictions and generalisations. They should be able to solve problems through research, applying knowledge and through practical work in the field and laboratory. Planning and organising skills should be developed through practical work. The use of information technology should include interfacing equipment and data handling software. Candidates should be able to identify hazards, assess risk and suggest control measures and to make ethical decisions based on relevant information and the consequences of a course of action.

UNIT 1 — Cells and Proteins

Introduction

This Unit focuses on the key role that proteins play in the structure and functioning of cells and organisms. In considering the proteome it builds on the understanding of the genome developed in the revised Higher Biology and Higher Human Biology Courses. The ability of proteins to fold into specific conformations and bind tightly to particular regions of other molecules provides the molecular diversity and activity necessary for the workings of a cell. This flexibility allows proteins to fill roles as enzymes, signals, receptors, channels, transporters and structural components. Signal transduction in particular allows the communication between cells necessary within multicellular organisms, and it is the emergent properties of protein-based signaling pathways that lead to the physiology of whole organisms.

The study of protein is primarily a laboratory-based activity, and consequently the Unit begins with a selection of important laboratory techniques for biologists. This skills-based sequence of concepts leads from health and safety considerations, through the use of liquids and solutions, to a selection of relevant separation and antibody techniques. In addition, much work on cell biology is based on the use of cell lines, so techniques related to cell culture and microscopy are included. The teaching of these techniques could be delivered in an integrated manner within this Unit.

Protein structure is introduced in terms of amino acid sequence, R-group classification and peptide bonds. The primary sequence of polypeptides determines the regions that will form secondary structure. The chemical interactions that cause the folding of tertiary structure are introduced; they are the same interactions that are important in the binding and conformational changes in functional polypeptides. Practical techniques, such as chromatography and electrophoresis, would be appropriate here for the analysis of amino acids and proteins.

Many proteins are associated with membranes and are responsible for the movement of molecules across the membrane. The development of the fluid-mosaic model of membrane structure provides a good opportunity to consider the evidence-based refinement of scientific thinking. The study of opsins allows the opportunity to explore a sensory mechanism and the amplification of a signal by cascade. The roles of signals and receptor molecules are developed in the study of communication within multicellular organisms. An area suitable for case study here could be diabetes, both of the types associated with the control of carbohydrate metabolism as well as those relating to the protein pore aquaporin 2 and its link to the peptide hormone ADH. These are good examples of how the study of molecular interactions leads to a greater understanding of physiology and medicine. The pump protein Na/KATPase provides insight into the functioning of neurones, which can provide the context for a number of investigative practicals.

Structural proteins are also of great importance in the normal functioning of cells, whether in terms of cytoskeleton or muscular contraction and movement. The latter provides another good context for the teaching of experimental design. Cell division provides a final case study for the holistic synthesis of these various cellular events. The roles of proteins in both normal mitosis and abnormal cell division are considered. As with many other parts of this Unit this is an area where students will want to consider the impact of their understanding in a wider context.

National Course specification: Course details (cont)

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CONTENT	NOTES	CONTEXTS
1 Laboratory techniques for biologists		
(a) Health and safety	Chemicals or organisms can be intrinsically hazardous. Their use may involve risks to people, to other organisms or to the environment. The use of control measures, including personal protective equipment as a last resort, to reduce risk.	Standard laboratory rules and familiarity with risk assessment.
(b) Liquids and solutions	Use of cylinders, pipettes, burettes, autopipettors and syringes. Dilution series are often linear or log. pH can be measured using a meter or an indicator. Buffers allow the pH of a solution to be controlled. Standard curve and determination of an unknown. The concentration of a pigmented compound can be quantified using a colorimeter.	Practice measuring and making solutions and using buffers before embarking upon important experimentation. Use a colorimeter or spectrophotometer to calibrate a known solution and determine an unknown using, for example, Bradford reagent.
(c) Separation techniques	Centrifugation to separate pellet and supernatant of differing density. Paper, thin layer and affinity chromatography for amino acids and proteins. Protein electrophoresis uses current flowing through a buffer to separate proteins. Proteins can be separated using pH; at their iso-electric point they have an overall neutral charge and precipitate out of solution.	Use protein electrophoresis to identify different muscle proteins. Determine the iso-electric point of a soluble protein such as casein.
(d) Antibody techniques	Antibodies are widely used in the detection and identification of specific proteins. Immunoassay techniques use antibodies linked to reporter enzymes to cause a colour change in the presence of a specific antigen. Fluorescent labelling of antibodies in blotting and (immunohistochemical) staining of tissue.	Use of monoclonal antibodies in the diagnosis and detection of disease. Use the ELISA technique to identify the presence of specific antigens.

National Course specification: Course details (cont)

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CONTENT	NOTES	CONTEXTS
(d) Antibody techniques (cont)	To produce stocks of a particular antibody, hybridomas are formed by fusion of a B lymphocyte with a myeloma cell using polyethelene glycol (PEG).	
(e) Microscopy	Use of bright field to examine whole organisms, parts of organisms or thin sections of dissected tissue. Haemocytometers and flow cytometry. Fluorescence microscopy allows particular protein structures to be visualised.	Refresh skills in the use of microscope and making slides. Discuss the ethics of dissection in an educational context.
(f) Aseptic technique and cell culture	Sterilisation of containers, equipment and materials. Disinfection of working area. Culture media contain requirements of the cells. Use of inoculum, explants or cells. Viable and total cell counts. Complex media containing growth factors from serum for animal cell lines. Lifetime of primary cell lines and cancer cell lines in culture. Use of growth regulators in plant tissue culture.	Culture bacterial, yeast and algal cells using aseptic technique. Use a haemocytometer to make an estimate of cell count.

National Course specification: Course details (cont)

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CONTENT	NOTES	CONTEXTS
2 Proteins		
(a) Proteomics	The proteome is the entire set of proteins expressed by a genome. RNA splicing and post-translational modification results in the proteome being larger than the genome. Due to regulation of gene expression not all genes are expressed as proteins in a particular cell. While DNA sequencing and microarray technology allow the routine analysis of the genome and transcriptome, the analysis of the proteome is far more complex. The distinguishing feature of protein molecules is their folded nature and their ability to bind tightly and specifically to other molecules. Binding causes a conformational change in the protein, which may result in an altered function, and may be reversible. Proteins may have one or more stable conformations depending on binding.	
(b) Protein structure, binding and conformational change		
(i) Amino acid sequence determines protein structure	Proteins are polymers of amino acid monomers. Amino acids link by peptide bonds to form polypeptides. The primary sequence is the order in which the amino acids are synthesised into the polypeptide. Hydrogen bonding along the backbone of the protein strand results in regions of secondary structure — alpha helices, parallel or anti-parallel beta sheets, or turns. Identification of main classes of R groups (residues or sidechains) of the 20 amino acids based on functional group: positively charged; negatively charged; polar; hydrophobic; other. Individual names or structures not required.	Use amino acid chromatography to distinguish between different amino acids. Use protein electrophoresis to identify different muscle proteins. Determine the iso-electric point of a protein and explain the result using understanding of protein structure. Molecular modelling eg computer aided drug design.

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CONTENT	NOTES	CONTEXTS
(i) Amino acid sequence determines protein structure (cont)	The polypeptide folds into a tertiary structure; this conformation is caused by charge effects, such as interactions of the R groups in hydrophobic regions, ionic bonds, hydrogen bonds, van der Waals interactions and disulfide bridges. Prosthetic groups give proteins added function, eg haem in haemoglobin. Quaternary structure exists in proteins with several connected polypeptide subunits. Interactions of the R groups can be influenced by temperature and pH.	Primary structure comparisons of enzymes from different evolutionary backgrounds — alcohol dehydrogenase from different organisms. Post-translational modification and activity in trypsinogen and trypsin.
(ii) Hydrophobic and hydrophilic interactions influence the location of cellular proteins	The R groups at the surface of a protein determine its location within a cell. Hydrophilic R groups will predominate at the surface of a soluble protein found in the cytoplasm. In these proteins, hydrophobic R groups may cluster at the centre to form a globular structure. The fluid mosaic model of membrane structure. Regions of hydrophobic R groups allow strong hydrophobic interactions that hold integral proteins within the phospholipid bilayer. Some integral proteins are transmembrane, for example channels, transporters and many receptors. Peripheral proteins have fewer hydrophobic R groups interacting with the phospholipids.	Look at history of evidence-based models of membrane structure as an example of refinement of scientific ideas.

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CONTENT	NOTES	CONTEXTS
(iii) Binding to ligands	A ligand is a substance that can bind to a protein. R groups not involved in protein folding can allow binding to these other molecules. Binding sites will have complementary shape and chemistry to the ligand. DNA binds to a number of proteins. Positively charged histone proteins bind to the negatively charged sugar–phosphate backbone of DNA in eukaryotes; the DNA is wrapped around histones to form nucleosomes packing the DNA in chromosomes. Other proteins have binding sites that are specific to particular sequences of double stranded DNA and when bound to can either stimulate or inhibit initiation of transcription.	
(iv) Binding changes the conformation of a protein	As a ligand binds to a protein binding site, or a substrate binds to an enzyme's active site, the conformation of the protein changes. This change in conformation causes a functional change in the protein. In enzymes, specificity between the active site and substrate is related to induced fit. When the correct substrate starts to bind, a temporary change in shape of the active site occurs increasing the binding and interaction with the substrate. The chemical environment produced lowers the activation energy required for the reaction. Once catalysis takes place, the original enzyme conformation is resumed and products are released from the active site.	Enzyme kinetic studies measure turnover rate and affinity. Importance of measuring the initial rate of reaction in enzyme kinetics studies. The impact of inhibitors on enzyme kinetics.

National Course specification: Course details (cont)

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CONTENT	NOTES	CONTEXTS
(iv) Binding changes the conformation of a protein (cont)	In allosteric enzymes, modulators bind at secondary binding sites. The conformation of the enzyme changes and this alters the affinity of the active site for the substrate. Positive modulators increase the enzyme affinity whereas negative modulators reduce the enzyme's affinity for the substrate. Some proteins with quaternary structure show cooperativity in which changes in binding at one subunit alter the affinity of the remaining subunits. Cooperativity in the binding and release of oxygen in haemoglobin and the influence of temperature and pH.	 Analyse haemoglobin dissociation curves.
(v) Reversible binding of phosphate and control of conformation	The addition or removal of phosphate from particular R groups can be used to cause reversible conformational changes in proteins. This is a common form of post-translational modification. In this way the activity of many cellular proteins such as enzymes and receptors are regulated. Kinase is often responsible for phosphorylation of other proteins and phosphatase catalyses dephosphorylation. Some proteins (ATPases) use ATP for their phosphorylation. Myosin has heads that act as cross bridges as they bind to actin. When ATP binds to myosin, the myosin head detaches from actin, swings forwards and rebinds. The rebinding releases the ADP and a phosphate ion drags the myosin along the actin filament.	 Muscle contraction experiment using ATP. An opportunity to focus on experimental design associated with pilot studies, measurement accuracy, sample size and replication.

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CONTENT	NOTES	CONTEXTS
(c) Membrane proteins		
(i) Movement of molecules across membranes	The phospholipid bilayer as a barrier to ions and most uncharged polar molecules. Some small molecules such as oxygen and carbon dioxide pass through. Specific transmembrane proteins, which act as channels or transporters, control ion concentrations and concentration gradients. To perform specialized functions, different cell types and different cell compartments have different channel and transporter proteins. Passage of molecules through channel proteins is passive (eg aquaporin). Some channel proteins are gated and change conformation to allow or prevent diffusion (eg sodium channels, potassium channels). 'Gated' channels can be controlled by signal molecules (ligand-gated channels) or changes in ion concentrations (voltage-gated channels). Transporter proteins change conformation to transport molecules across a membrane. Transport can be facilitated (eg glucose symport) or active (eg Na/KATPase). Conformational change in active transport requires energy from hydrolysis of ATP.	CFTR, mutation and cystic fibrosis.
(ii) Signal transduction	Some cell surface receptor proteins convert an extracellular chemical signal to a specific intracellular response through a signal transduction pathway. This may result in the activation of an enzyme or G protein, a change in uptake or secretion of molecules, rearrangement of the cytoskeleton or activation of proteins that regulate gene transcription.	

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CONTENT	NOTES	CONTEXTS
(iii) Ion transport pumps and generation of ion gradients	The sodium potassium pump transports ions against a steep concentration gradient using energy directly from ATP. The transporter protein has high affinity for sodium ions inside the cell; binding occurs; phosphorylation by ATP; conformation changes; affinity for ions changes; sodium ions released outside of the cell, potassium ions bind outside the cell; dephosphorylation; conformation changes; potassium ions taken into cell; affinity returns to start. Functions of Na/KATPase include the following examples: maintaining the osmotic balance in animal cells; generation of the ion gradient for glucose symport in small intestine; generation and long-term maintenance of ion gradient for resting potential in neurons; generation of ion gradient in kidney tubules. The maintenance of ion gradients by Na/KATPase accounts for a significant part of basal metabolic rate (up to 25% in humans).	
(iv) Ion channels and nerve transmission	Nerve transmission is a wave of depolarisation of the resting potential of a neuron. This can be stimulated when an appropriate signal molecule, such as a neurotransmitter, triggers the opening of ligand-gated ion channels. If sufficient ion movement occurs, then voltage-gated ion channels will open and the effect travels along the length of the nerve. Once the wave of depolarisation has passed, these channel proteins close and others open to allow the movement of ions in the opposite direction to restore the resting potential.	Daphnia heart rate investigation. The action of chemical agonists can be assessed. The study can be an opportunity to focus on aspects of experimental design associated with pilot studies, measurement accuracy, sample size and replication. Human reaction time: consider the effects of age or caffeine. Block the design to avoid gender becoming a confounding variable.

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CONTENT	NOTES	CONTEXTS
(d) Detecting and amplifying an environmental stimulus		
(i) Photoreceptor protein systems	Photoreceptor system proteins are found across the three domains. In archaea, bacteriorhodopsin molecules generate potential differences by absorbing light to pump protons across the membrane. In plants the light absorbed by photosynthetic pigments drives an electron flow that pumps hydrogen ions across the thylakoid membrane of the chloroplast. In both cases the resulting diffusion of hydrogen ions back across the membrane drives ATP synthase. In animals the light-sensitive molecule retinal is combined with a membrane protein opsin and a cascade of proteins amplifies the signal. In cone cells, different forms of opsin give sensitivity to specific wavelengths (red, green, blue or UV). In rod cells, the rhodopsin absorbs a wider range of wavelengths and a greater degree of amplification by the protein cascade results in a sensitivity at low light intensities. When stimulated by one photon, a rhodopsin molecule activates hundreds of G-protein molecules, which activate hundreds of molecules of an enzyme. If the enzyme triggers sufficient product formation, a nerve impulse may be generated.	Investigate vision experimentally. Eyes, in which the light sensitive cells are grouped into organized structures for vision, appear to be give an evolutionary advantage; eyes are found in only six animal phyla yet are present in 95% of all animal species. Fish eye dissection.

National Course specification: Course details (cont)

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CONTENT	NOTES	CONTEXTS
(e) Communication within multicellular organisms		
(i) Coordination	Multicellular organisms achieve coordination through extracellular signalling molecules, receptors and responses. Receptor molecules of target cells are proteins with a binding site for a signal molecule. Binding changes the conformation of the receptor and this can alter the response of the cell. Different cell types produce specific signals which can only be detected and responded to by cells with the specific receptor. In a multicellular organism different cell types may show a tissue specific response to the same signal.	
(ii) Hydrophobic signals and control of transcription	Hydrophobic signalling molecules include the thyroid hormone thyroxine and steroid hormones. Hydrophobic signals can pass through membranes so their receptor molecules can be within the nucleus. Hydrophobic signals can directly influence transcription of genes. Thyroid hormone receptor protein binds to DNA in the absence of thyroxine and inhibits transcription of the gene for Na/KATPase. When thyroxine binds to the receptor protein, conformational change prevents the protein binding to the DNA and transcription of the gene for Na/KATPase can begin raising metabolic rate. The receptor proteins for steroid hormones (for example the sex hormones) are transcription factors. Only once the hormone signal has bound to the receptor can the transcription factor bind to gene regulatory sequences of DNA for transcription to occur.	 Case study of thyroid disorders. Case study of sex hormone disorders.

National Course specification: Course details (cont)

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CONTENT	NOTES	CONTEXTS
(iii) Hydrophilic signals and transduction	Hydrophilic signalling molecules include peptide hormones and neurotransmitters. Hydrophilic signals require receptor molecules to be at the surface of the cell. Transmembrane receptors change conformation when the ligand binds outside the cell; the signal molecule does not enter the cell but the signal is transduced across the membrane of the cell. Transduced hydrophilic signals often involve cascades of G-proteins or phosphorylation by kinase enzymes. Binding of the peptide hormone insulin to its receptor triggers recruitment of GLUT4 glucose transporter to the cell membrane of fat and muscle cells. Diabetes can be caused by failure to produce insulin (type 1) or loss of receptor function (type 2). Type 2 generally associated with obesity. Exercise also triggers recruitment of GLUT4, so can improve uptake of glucose to fat and muscle cells in subjects with Type 2. Binding of peptide hormone ADH to its receptor in collecting duct of kidney triggers recruitment of channel protein aquaporin 2 (AQP2). Aquaporins provide a highly efficient route for water to move across membranes. Recruitment of AQP2 allows control of water balance in terrestrial vertebrates. Failure to produce ADH or insensitivity of its receptor results in diabetes insipidus.	Examine data from glucose tolerance tests. Write a review of data from studies of health and wellbeing, considering the importance of publication of negative results. Find out about health effects associated with type 2 diabetes and the success rate of treatment programmes. Comparative anatomy and physiology of kidneys across different groups of animals.

National Course specification: Course details (cont)

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CONTENT	NOTES	CONTEXTS
(f) Protein control of cell division		
(i) Cell division requires the remodelling of the cell's cytoskeleton	The cytoskeleton gives mechanical support and shape to cells. The cytoskeleton consists of different types of proteins extending throughout the cytoplasm. Microtubules composed of hollow straight rods made of globular proteins called tubulins govern the location and movement of membrane-bound organelles and other cell components. Microtubules are found in all eukaryotic cells and radiate from the centrosome (the microtubule organizing centre). Microtubules form the spindle fibres, which are active during cell division.	Consider the effects of colchicine and paclitaxel on the cytoskeleton
(ii) The cell cycle	The cell cycle regulates the growth and replacement of genetically identical cells throughout the life of the organism. An uncontrolled reduction in the rate of the cell cycle may result in degenerative disease. An uncontrolled increase in the rate of the cell cycle may result in tumour formation. The cell cycle consists of interphase and mitosis. Interphase consists of an initial growth phase G_1 followed by an S phase where the cell continues to grow and copies its chromosomes in preparation for mitosis and a further G_2 growth phase. Mitosis is a dynamic continuum of sequential changes described as prophase, metaphase, anaphase and telophase. Role of spindle fibres in the movement of chromosomes on metaphase plate, separation of sister chromatids and formation of daughter nuclei. Cytokinesis as the separation of the cytoplasm into daughter cells.	Stain actively dividing plant meristem tissue and calculate a mitotic index. Examine the role of cell cycle regulators in degenerative diseases such as Alzheimer's and Parkinson's.

National Course specification: Course details (cont)

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CONTENT	NOTES	CONTEXTS
(iii) Control of the cell cycle	Progression through the cell cycle is regulated by checkpoints at G_1, G_2 and metaphase. Checkpoints are critical control points where stop and go ahead signals regulate the cycle. For many cells the G_1 checkpoint is the most important. If a go ahead signal is not reached at the G_1 checkpoint the cell switches to a non dividing state called the G_0 phase. As the cell size increases during G_1 cyclin proteins accumulate and combine with kinases to form regulatory protein molecules known as cyclin-dependant kinases (Cdks). Cdks cause the phosphorylation of proteins that stimulate the cell cycle. If a sufficient threshold of phosphorylation is reached the cell cycle moves on to the next stage. If an insufficient threshold is reached, the cell is held at a checkpoint. The G_1 Cdk phosphorylates a transcription factor inhibitor, retinoblastoma (Rb) protein, allowing DNA replication in the S phase. DNA damage triggers the activation of several proteins including p53 that can stimulate DNA repair, arrest the cell cycle or cause cell death.	Use an on-line simulation of mitotic checkpoint control. Investigate cell cycle mutation in yeast *Shizosaccharomyces pombe*. Research the types of mutations associated with cancer. For example the influence of environmental factors and viruses, the conversion of proto-oncogenes into oncogenes and mutations in tumour suppressing genes.

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CONTENT	NOTES	CONTEXTS
(iv) Control of apoptosis	The destruction of cells must be carefully controlled in a multicellular organism. Programmed cell death (apoptosis) is triggered by cell death signals that activate inactive forms of DNAase and proteinases (collectively known as caspases) that destroy the cell. Cell death signals may originate outwith the cell (for example from lymphocytes) and bind to a surface receptor protein to activate a protein cascade that produces active caspases. Death signals may also originate within the cell, for example as a result of DNA damage the presence of p53 protein can activate a caspase cascade. In the absence of cell growth factors cells may also initiate apoptosis.	Consider apoptosis in development of tetrapod limbs Research the challenges in overcoming apoptosis in maintaining animal cell culture lines.

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UNIT 2 — Organisms and Evolution

Introduction

This Unit explores the importance of parasites in evolution. It builds on the understanding of genomics, inheritance, parasitism and disease developed in the revised Higher Biology and revised Higher Human Biology Courses. To further ensure parity in progressing from either revised Higher Course, this Unit introduces concepts in a way that does not disadvantage learners from either Course. The majority of living species on the planet are parasitic, and, naturally, the species that are not parasites are almost certainly parasitised by them. The evolutionary 'arms race' between parasites and their hosts requires the constant reshuffling of biological variation that can only be achieved through meiosis. On a macroevolutionary scale, parasites are often considered to be responsible for the maintenance of sexual reproduction. On a microevolutionary scale, mate choice behaviour is often correlated with parasite avoidance.

Biological variation is a central concept in this Unit. Variation is best observed in the natural environment, so this Unit begins with an outline of suitable techniques for ecological field study. Methods of sampling and the classification and identification of organisms are considered. In classification there is a focus on those groups that are commonly parasitic. Mark and recapture is included as one method of estimating population size. For animal behaviour studies, ethograms, time sampling and the avoidance of anthropomorphism are emphasised. The teaching of these techniques could be delivered in an integrated manner within the Unit.

Evolution is considered from the impact of drift and selection on variation. Factors influencing the rate of evolution, relative fitness and the co-evolution of species are also introduced to set the context for a consideration of the evolutionary importance of sex and parasites. The costs and benefits of sexual and asexual reproduction are considered including the role of meiosis in variation. In field studies there is a direct link between variation in populations as a result of recombination and the need for a representative sample size in data collection. Parthenogenic and hermaphroditic organisms are considered as well as the various factors that can determine sex. This provides an opportunity for laboratory work on sex-linked inheritance patterns as well as an opportunity to extend learning into the epigenetic concept of X-chromosome inactivation. The study of sexual behaviour provides opportunities to use the techniques of ethology. The focus is on sexual selection during courtship, whether as a result of male rivalry or female choice, and suggested areas of study are in birds, insects and fish. The concept of optimality underlies the understanding of reproductive investment and strategies.

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Finally the Unit considers the parasite niche. The relationship between transmission and virulence is explored as well as the ability of parasites to modify the behaviour of their hosts. The mammalian immune system is introduced along with parasitic counter measures. Co-evolution between hosts and their parasites is considered under the Red Queen's hypothesis. Microparasites are introduced including RNA retroviruses. The complex lifecycles and diseases associated with some of the major macroparasites are also considered.

There is much opportunity within the Unit to explore the systems approach required for the understanding of parasite biology. In addition, as human and agricultural parasite burden and virulence is shared so unequally among the world's population, there will be much opportunity to explore wider ethical issues relating to the importance of scientific knowledge and its application in challenging social and economic circumstances.

National Course specification: Course details (cont)

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CONTENT	**NOTES**	**CONTEXTS**
1 Field techniques for biologists		
(a) Health and safety	Fieldwork may involve a wider range of hazards compared with working in the laboratory. Hazards and risks associated with terrain, weather conditions and isolation must be assessed.	Discuss standard rules for fieldwork safety.
(b) Sampling wild organisms	Sampling should be carried out in a manner that minimizes impact on wild species and habitats. Consideration must be given to rare and vulnerable species and habitats, which are protected by legislation. The chosen technique, such as point count, transect or remote detection, must be appropriate to the species being sampled. Quadrats of suitable size and shape are used for slow-moving organisms; capture techniques for mobile species. Elusive species can be sampled directly using camera traps or an indirect method such as scat sampling.	Participate in fieldwork using random, systematic and stratified sampling as appropriate. Identification of sample using guides and keys. Awareness of protected species in Scotland.
(c) Identification and taxonomy	Identification of a sample can be made using expertise, classification guides, keys or laboratory analysis of DNA, protein or other molecules. The classification of life according to relatedness is central to biological understanding. Familiarity with taxonomic groupings allows predictions and inferences to be made between the biology of an organism and better-known (model) organisms. Genetic evidence reveals relatedness obscured by divergent or convergent evolution.	In the context of fieldwork, sample the organisms from a variety of habitats and attempt to classify and catalogue them using keys and other materials. Visit a botanic garden to learn more about the major divisions of plants. Visit a zoological park to learn more about the animal phyla. Undertake fieldwork to study the invertebrate phyla commonly found on the shore, in a river or in a woodland.

National Course specification: Course details (cont)

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CONTENT	NOTES	CONTEXTS
(c) Identification and taxonomy (cont)	Life is classified into three domains, the archaea, bacteria and eukaryota. The plant kingdom has major divisions such as mosses, liverworts, ferns, conifers and flowering plants. The animal kingdom is divided into phyla, which include the Chordata (sea squirts and vertebrates), Arthropoda (joint-legged invertebrates: segmented body typically with paired appendages), Nematoda (round worms: very diverse, many parasitic), Platyhelminthes (flatworms: bilateral symmetry, internal organs but no body cavity, many parasitic) and Mollusca (molluscs: diverse, many with shells).	There are model organisms within all major taxonomic groups. Examples of model organisms include *E. coli*, *Saccharomyces cerevisiae*, *Arabidopsis thaliana*, maize, *C. elegans*, *Drosophila*, *Hydra*, lamprey, mouse, rat, zebrafish, chicken, zebra finch.
(d) Monitoring populations	Presence, absence or abundance of particular species can give information of environmental qualities, such as presence of pollutant. Classification of vegetation types is based on indicator species within the community structure. Mark and recapture is a method for estimating population size. A sample of the population is captured and marked (M) and released. After an interval of time, a second sample is captured (C). If some of the individuals in this second sample are recaptures (R) then the total population N = (MC)/R, assuming that all individuals have an equal chance of capture and that there is no immigration or emigration. Methods of marking include banding, tagging, surgical implantation, painting and hair clipping. The method of marking and subsequent observation must be effective and should also minimize the impact on the study species.	Identify relevant indicator species to classify a habitat using the British National Vegetation Classification. Carry out a mark and recapture experiment using a wild species or, alternatively, using school pupils to estimate the total school roll.

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CONTENT	NOTES	CONTEXTS
(e) Measuring and recording animal behaviour	An ethogram of the behaviours shown by a species in a wild context allows the construction of time budgets. Measurements such as latency, frequency and duration. The importance of avoiding anthropomorphism.	Use an ethogram and time sampling to compare the behaviour of different individuals of a species.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

CONTENT	NOTES	CONTEXTS
2 Organisms		
(a) Evolution		
(i) Drift and selection	Evolution is the change over time in the proportion of individuals in a population differing in one or more inherited traits. Evolution can occur through the random processes of genetic drift or the non-random processes of natural selection and sexual selection. Genetic drift is more important in small populations, as alleles are more likely to be lost from the gene pool. Variation in traits arises as a result of mutation. Mutation is the original source of new sequences of DNA. These new sequences can be novel alleles. Most mutations are harmful or neutral but in rare cases they may be beneficial to the fitness of an individual. Fitness can be defined in absolute or relative terms. Absolute fitness is the ratio of frequencies of a particular genotype from one generation to the next. Relative fitness is the ratio of surviving offspring of one genotype compared with other genotypes. As organisms produce more offspring than the environment can support, those individuals with variations that best fit their environment are the ones most likely to survive and breed. Through inheritance, these favoured traits are therefore likely to become more frequent in subsequent generations.	

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

CONTENT	NOTES	CONTEXTS
(a) Evolution (cont)		
(ii) Rate of evolution	Where selection pressures are high, the rate of evolution can be rapid. The rate of evolution can be increased by factors such as shorter generation times, warmer environments, the sharing of beneficial DNA sequences between different lineages through sexual reproduction and horizontal gene transfer.	Comparison of cladograms of MRSA and primate evolution to compare the effect of generation time on rates of evolution. Investigate horizontal gene transfer using X-bacteria.
(iii) Co-evolution and the Red Queen	Co-evolution is frequently seen in pairs of species that interact frequently or closely. Examples include herbivores and plants, pollinators and plants, predators and their prey, and parasites and their hosts. In co-evolution, a change in the traits of one species acts as a selection pressure on the other species. The co-evolutionary 'arms race' between a parasite and host is known as the Red Queen as both organisms must 'keep running in order to stay still'. Hosts better able to resist and tolerate parasitism have greater fitness. Parasites better able to feed, reproduce and find new hosts have greater fitness.	Read excerpts from Matt Ridley's book *The Red Queen*. Case study on HIV and CD4 variability or evolution of *Plasmodium falciparum* and *P. vivax* with reference to primate evolution.

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CONTENT	NOTES	CONTEXTS
(b) Variation and sexual reproduction		
(i) Costs and benefits of reproduction	Compared to asexual reproduction, sexual reproduction appears to have two disadvantages. First, half of the population are unable to produce offspring – this is known as the paradox of the existence of males. Second, by mixing the genetic information between two individuals, each parent disrupts a successful genome and only passes on half to each offspring. Given that sexual reproduction is so widespread, the benefits must outweigh these disadvantages. The benefit lies in the greater genetic variation within sexually reproducing organisms. This genetic variation provides the raw material required to keep running in the Red Queen's arms race between parasites and their hosts. Asexual reproduction can be a successful reproductive strategy, particularly in very narrow stable niches or when recolonising disturbed habitats. In eukaryotes, examples of asexual reproduction include vegetative cloning in plants and parthenogenic animals that lack fertilisation. Parthenogensis is more common in cooler climates with low parasite diversity. For organisms that reproduce principally by asexual reproduction, many have mechanisms for horizontal gene transfer between individuals, such as the plasmids of bacteria and yeast.	Consider how the evolutionary importance of sexual reproduction influences experimental design in the life sciences: the natural variation generated means that biologists have to take care when sampling a population and analysing data to make sure that they can distinguish this 'noise' from any experimental result or 'signal'. Examine reproduction in a parthenogenic organism such as the laboratory stick insect *Carausias morosus* (in which offspring are female) and compare with the Komodo dragon (in which offspring are male).

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

CONTENT	NOTES	CONTEXTS
(ii) Meiosis forms variable gametes	The production of haploid gametes by meiosis. Knowledge of the terms meiosis I, meiosis II, gamete mother cell, chromosome, chromatid. Homologous chromosomes are pairs of chromosomes of the same size, same centromere position and with the same genes at the same loci. Each homologous chromosome is inherited from a different parent, therefore the alleles of the genes of homologous chromosomes may be different. Crossing over occurs at chiasmata during meiosis I. This process shuffles sections of DNA between the homologous pairs allowing the recombination of alleles to occur. Genes on the same chromosome are said to be linked. Correlation of the distance between linked genes and their frequency of recombination.	Use microscopy to examine gamete formation or gametes in plants or invertebrates.
	Independent assortment occurs as a result of meiosis I with homologous chromosomes being separated irrespective of their maternal and paternal origin. In many organisms, gametes are formed directly from the cells produced by meiosis. In other groups, mitosis may occur after meiosis to form a haploid organism; gametes form later by differentiation.	Breed model organisms in the laboratory (eg *Drosophila* or rapid-cycling *Brassica*) to demonstrate independent assortment or, if possible, recombination.

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CONTENT	NOTES	CONTEXTS
(iii) Sex determination	Many species are hermaphroditic. For some species environmental rather than genetic factors determine sex. Environmental sex determination in reptiles controlled by environmental temperature of egg incubation. Sex can change in some species as a result of size, competition or parasitic infection. Sex chromosomes, such as XY in live-bearing mammals and some insects including *Drosophila*. In many of the mammals a gene on the Y chromosome determines development of maleness. In some species the sex ratio of offspring can be adjusted in response to resource availability.	Examine data on sex determination in a variety of organisms. Research sex-ratio manipulation in red deer. Compare the flowers of hermaphroditic and unisexual plants.
	In live-bearing mammals, the heterogametic (XY) male lacks homologous alleles on the smaller (Y) chromosome. This can result in sex-linked patterns of inheritance as seen with carrier females (X^BX^b) and affected males (X^bY). In the females, the portions of the X chromosome that are lacking on the Y chromosome are randomly inactivated in one of the homologous X chromosomes in each cell. This effect prevents a double-dose of gene products. Carriers remain unaffected by any deleterious mutations on these X chromosomes as the X-chromosome inactivation is random, half of the cells in any tissue will have a working copy of the gene in question.	Use *Drosophila* to investigate sex-linked inheritance patterns. Examine data on inheritance patterns of tortoiseshell cats. Case study on X linked agammaglobulinemia and colour vision defect.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

CONTENT	NOTES	CONTEXTS
(c) Sex and behaviour		
(i) Sexual investment	Comparison of sperm and egg production in relation to number and energy store; greater investment by females. Problem and solutions of sex for sessile organisms. Costs and benefits of external and internal fertilisation. Parental investment is costly but increases the probability of production and survival of young. Simplistic classification of parental investment into discrete r-selected and k-selected organisms does not reflect continuous range of life history strategies. Optimal reproduction in terms of the number and quality of current offspring versus potential future offspring. Various reproductive strategies have evolved ranging from polygamy to monogamy.	Investigate foraging/pollinating behaviour of insects at flowers. Investigate a range of reproductive strategies using examples such as naked mole rats.
(ii) Courtship	Sexual dimorphism as a product of sexual selection. Male–male rivalry: large size or weaponry increases access to females through conflict. Alternatively some males are successful by acting as sneakers. Female choice: males have more conspicuous markings, structures and behaviours. Females assess honest signals to assess the fitness of males. Fitness can be in terms of good genes and low parasite burden. In lekking species, alternative successful strategies of dominant and satellite males. Females generally inconspicuous. Reversed sexual dimorphism in some species.	Courtship in the field: create an ethogram observing the ritualised courtship displays of water birds such as grebes or ducks. Courtship in the laboratory: observe stickleback or *Drosophila* courtship; investigate sexual selection in different *Drosophila* varieties. Research honest signalling in lekking species.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

CONTENT	NOTES	CONTEXTS
(ii) Courtship (cont)	Successful courtship behaviour in birds and fish can be a result of species-specific sign stimuli and fixed action pattern responses. Imprinting, an irreversible developmental processes that occurs during a critical time period in young birds, may influence mate choice later in life.	
(d) Parasitism		
(i) The parasite niche	At least half of all species are parasitic, and all free-living species are thought to host parasites. A parasite is a symbiont that gains benefit in terms of nutrients at the expense of its host. Unlike in a predator–prey relationship, the reproductive potential of the parasite is greater than that of the host. An ecological niche is a multidimensional summary of tolerances and requirements of a species. Parasites tend to have a narrow niche as they have high host specificity. As the host provides so many of the parasite's needs, many parasites are degenerate, lacking in structures and organs found in other organisms. The niche for an ectoparasite is on the surface of its host, whereas an endoparasite lives within the host. The organism on or in which the parasite reaches sexual maturity is the definitive host. Intermediate hosts may also be required for the parasite to complete its life cycle. A vector plays an active role in the transmission of the parasite and may also be a host.	Research the niche of *C. difficile* and the use of feacal transplants.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

CONTENT	NOTES	CONTEXTS
(i) The parasite niche (cont)	In ecology, a species has a fundamental niche that it occupies in the absence of any interspecific competing influences. A realised niche is occupied in response to interspecific competition. As a result of interspecific competition, competitive exclusion can occur where the niches of two species are so similar that one declines to local extinction. Where the realised niches are sufficiently different, potential competitors can co-exist by resource partitioning.	
(ii) Transmission and virulence	Transmission is the spread of a parasite to a host. Virulence is the harm caused to a host by a parasite. A higher rate of transmission is linked to higher virulence. Factors that increase transmission rates include the overcrowding of hosts at high density, or mechanisms that allow the parasite to spread even when infected hosts are incapacitated. Vectors and waterborne dispersal stages are examples of the latter. Host behaviour is often exploited and modified by parasites to maximise transmission. Through the alteration of host foraging, movement, sexual behaviour, habitat choice or anti-predator behaviour, the host behaviour becomes part of the extended phenotype of the parasite. Parasites also often suppress the host immune system and modify host size and reproductive rate in ways that benefit the parasite growth reproduction or transmission. The distribution of parasites is not uniform across hosts. Sexual and asexual phases allow rapid evolution and rapid build-up of parasite population. The most successful parasites have efficient modes of transmission and rapid rates of evolution.	Investigate the spread of a plant pathogen in a variety of planting densities and humidities. Consider the potential socioeconomic impact of plant pathogens, such as blight.

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CONTENT	NOTES	CONTEXTS
(iii) Immune response to parasites	Non-specific defences of mammals: physical barriers, chemical secretions, inflammatory response, phagocytes and natural killer cells destroying abnormal cells. Specific cellular defence in mammals involves immune surveillance by white blood cells, clonal selection of T lymphocytes, T lymphocytes targeting immune response and destroying infected cells by inducing apoptosis, phagocytes presenting antigens to B lymphocytes, the clonal selection of B lymphocytes, production of specific antibody by B lymphocyte clones, long term survival of some members of T and B lymphocyte clones to act as immunological memory cells. Epidemiology is the study of the outbreak and spread of infectious disease. The herd immunity threshold is the density of resistant hosts in the population required to prevent an epidemic. Endoparasites mimic host antigens to evade detection by the immune system, and modify host-immune response to reduce their chances of destruction. Antigenic variation in some parasites allows them to evolve fast enough for them to be one step ahead of host immune cell clonal selection.	 Use a statistical test to confirm or refute the significance of results of an epidemiological study into disease.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

CONTENT	NOTES	CONTEXTS
(iv) Macroparasitic life cycles	Macroparasites are typically endoparasitic amoebas, platyhelminths or nematodes or ectoparasitic arthropods. Ectoparasites and endoparasites of the main body cavities, such as the gut, are generally transmitted by direct contact or through consumption of secondary hosts. Endoparasites of the body tissues are often transmitted by vectors. Schistosomiasis and malaria as examples of human diseases caused by a macroparasites.	Consider the ecology, evolution, reproduction and physiology of a selected human parasite. Consider how attempts to disrupt the lifecycle of *Plasmodium* in the control of malaria have resulted in the loss of apex predators due to bio-magnification of the organochloride insecticide DDT.
(v) Microparasites	Microparasites include viruses and bacteria. Influenza, HIV and tuberculosis as human diseases caused by microparasites. Viruses are infectious agents that can only replicate inside a host cell. Viruses contain genetic material in the form of DNA or RNA, packaged in a protective protein coat. Some viruses have a lipid membrane surround derived from host cell materials. The outer surface of a virus contains antigens that a host cell may or may not be able to detect as foreign. RNA retroviruses use the enzyme reverse transcriptase to form DNA, which is then inserted into the genome of the host cell. This virus gene forms new viral particles when transcribed.	Investigate the effects of a phage virus on bacterial growth. Most of the genome of most eukaryotic species consists of mobile or defunct retrotransposons, which are thought to have arisen from retroviruses. Active retrotransposons form new copies of themselves to be inserted elsewhere in the same genome. The genes responsible for the variability of vertebrate antibodies are thought to have evolved from transposons.

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CONTENT	NOTES	CONTEXTS
(vi) Challenges in treatment and control	There are many challenges to overcome in the successful treatment and control of parasites. Parasites are difficult to culture in the laboratory. Rapid antigen change has to be reflected in the design of vaccines. The similarities between host and parasite metabolism makes it difficult to find drug compounds that only target the parasite. Civil engineering projects to improve sanitation combined with coordinated vector control may often be the only practical control strategies. Unfortunately, parasites spread most rapidly in those conditions where coordinated treatment and control programs are most difficult to achieve. For example in overcrowded refugee camps that result from war or natural disasters. In addition parasites are more abundant in the tropical climates that are found in many developing countries. Improvements in parasite control reduce child mortality and result in population-wide improvements in child development and intelligence as individuals have more resources for growth and development.	Case study on parasitism and childhood. Research impact of parasitism on child mortality rates in developed and developing countries. Consider benefits of intervention programmes in terms of childhood development and intelligence. Research the decline of effectiveness of chemical treatments over time.

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UNIT 3 — Investigative Biology

Introduction

This Unit will give learners a solid grounding in both the principles and practice of investigative biology. Science is introduced as the gathering and organisation of knowledge, and particular focus is placed on the testability and refinement of knowledge through experimentation. This introduction will allow learners to relate their own experiences of scientific method within the world of science. Essential ethics for biologists, as well as an introduction to the purposes and forms of different types of scientific communication, are also covered.

The advancement of biological knowledge requires an understanding of the skills and practices of experimental design. As variation is a cornerstone of biology, a characteristic of the results of biological investigations is a high signal-to-noise ratio. To help discriminate between the effects of an experimental treatment and random variation in results, learners are introduced to the necessity for a sample to be representative of the population as a whole. Key to successful experimentation is the understanding of the interactions between independent, dependent and confounding variables. The complexity of biological systems means that the control of a large number of confounding variables must be considered. The importance of the use of pilot studies in establishing the appropriate experimental design is stressed. Consideration is also given to standard experimental designs as well as to concepts such as correlation versus causation and treatment versus control.

Learners are also introduced to the skills involved in analysis and evaluation of scientific reports. The validity of treatment and control procedures are more effectively evaluated through the deeper understanding of experimental design outlined above. The use of data analysis techniques to explore and confirm the significance of findings is described. While it may be useful for learners to experience the use of particular statistical tests, the Course focuses on developing the understanding that a statistically significant result is unlikely to have occurred by chance. In this way learners can gain skills in evaluation of the typically variable datasets generated by biological research.

The planning and carrying out of a 20 hour Biology Investigation is also part of this Unit. This Biology Investigation is designed to provide opportunities to further develop investigative skills through the completion of an investigation. It also provides the opportunity for self-motivation and organisation in the development of a plan for an investigation and the collection and analysis of information obtained.

It is envisaged that learners could cover the above content in a manner that is integrated across the other Units of the Course and based upon an appropriate mixture of practical work and stimulus material derived from scientific publications. In this way, learners will develop an understanding of the scientific thinking behind investigative skills, ideally before embarking on their own Biology Investigation.

COURSE Biology (revised) Advanced Higher

CONTENT	NOTES	CONTEXTS
1 Scientific principles and process		
(a) Scientific method	Science is the gathering and organisation of testable and reproducible knowledge. In the scientific cycle, hypothesis testing involves the gathering, recording and analysis of data, followed by the evaluation of results and conclusions. New hypotheses may then be formulated and tested. In science, refinement of ideas is the norm, and scientific knowledge can be thought of as the current best explanation which may then be updated after evaluation of further experimental evidence. Failure to find an effect (ie a negative result) is a valid finding, as long as an experiment is well designed. Conflicting data or conclusions can be resolved through careful evaluation or can lead to further, more creative, experimentation. The null hypothesis can be used in the design of experiments to investigate a possible effect. Scientific ideas only become accepted once they have been verified (or alternatives falsified) independently; one-off results are treated with caution.	Case study on the successive evidence-based models of the structure of the plasma membrane to illustrate refinement of scientific knowledge through a framework of experimentation. Discuss importance of publication of negative results in the fields of pharmaceutical or medical research, for example. Consider Karl Popper's concept of falsifiability as the basis for scientific thinking. Investigate examples of recent scientific breakthroughs to try to identify examples of unexpected results, conflicting data or creative experimentation. Consider also the impact of mental inertia on the advancement of science.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

CONTENT	NOTES	CONTEXTS
(b) Scientific literature and communication	The importance of publication of methods, data, analysis and conclusions in scientific reports so that others are able to repeat an experiment. Common methods of sharing original scientific findings include seminars, conference talks and posters and publishing in academic journals. Most scientific publications use peer review. Specialists with expertise in the relevant field assess the scientific quality of a submitted manuscript and make recommendations regarding its suitability for publication. Some journals also publish review articles, which summarise current knowledge and recent findings in a particular field. Critical evaluation of science coverage in the wider media. Increasing the public understanding of science and the issue of misrepresentation of science in the media.	Write a method that can be followed by another investigator. Follow the method provided by another investigator. Through (literal) replication, attempt to verify another investigator's results. Present scientific findings in a report suitable for a primary journal. Use a range of scientific sources to summarise several articles in a scientific review. Contrast the dispassionate approach taken in presenting scientific results with the passionate reality of scientific investigation (eg see Frederick Grinnell's *The Everyday Practice of Science*).
(c) Scientific ethics	While judgements and interpretations of scientific evidence may be disputed, integrity and honesty are of key importance in science. The replication of experiments by others reduces the opportunity for dishonesty or the deliberate misuse of science. The requirement to cite and supply references. In animal studies, the concepts of replacement, reduction and refinement are used to avoid, reduce or minimise the harm to animals. In human studies, informed consent, the right to withdraw data and confidentiality are important considerations.	Discuss excerpts from Ben Goldacre's *Bad Science.* Use an on-line plagiarism checker to check scientific writing. Using a standard system, make appropriate citations in a piece of scientific writing and construct a reference list that allows another investigator to locate your source material. Discuss the implications of Russell and Burch's 3Rs on school-based animal studies.

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CONTENT	NOTES	CONTEXTS
(c) Scientific ethics (cont)	The value or quality of science investigations must be justifiable in terms of the benefits of its outcome including the pursuit of scientific knowledge. The risk to and safety of subject species, individuals, investigators and the environment must be taken into account. As a result, many areas of scientific research are highly regulated and licensed by governments. Legislation limits the potential for the misuse of studies and data. Legislation, regulation, policy and funding can all influence the direction and pace of scientific progress.	Discuss the implications of the British Psychological Society's ethical guidelines on school-based investigations on humans. Discuss the impact of legislation, market forces, patents, government funding and charitable funding on scientific research.
2 Experimentation		
(a) Pilot study	Integral to the development of an investigation, a pilot study is used to help plan procedures, assess validity and check techniques. This allows evaluation and modification of experimental design. A pilot study can be used to develop a new protocol or to enable an investigator to become proficient in using an established protocol. The use of a pilot study can ensure an appropriate range of values for the independent variable to avoid results for the dependent variable ending up 'off the scale'. In addition, it allows the investigator to establish the number of repeat measurements required to give a true value for each independent datum point. A pilot study can also be used to check whether results can be produced in a suitable time frame.	Follow a multi-step protocol, such as protein electrophoresis, mitotic index or cell cycle mutation in yeast, to appreciate need for practice of difficult techniques. Use a pilot study to establish ranges for variables in an investigation such as enzyme activity or *Daphnia* heart rate. Carry out a pilot study for the Biology Investigation.

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CONTENT	NOTES	CONTEXTS
(b) Variables	Due to the complexities of biological systems, other variables besides the independent variable may affect the dependent variable. These confounding variables must be held constant if possible, or at least monitored so that their effect on the results can be accounted for in the analysis. In cases where confounding variables cannot easily be controlled, blocks of experimental and control groups can be distributed in such a way that the influence of any confounding variable is likely to be the same across the experimental and control groups. Variables can be discrete or continuous and give rise to qualitative, quantitative or ranked data. The type of variable being investigated has consequences for any graphical display or statistical tests that may be used.	Consider the operationalisation (ie what measurements are actually being taken) for a set of independent, dependent and confounding variables, for example in the context of an investigation into reproductive investment, courtship or mate choice in *Drosophila* or stickleback. Examine sources of data derived from qualitative, quantitative and ranked variables and decide how to analyse and present the results appropriately.
(c) Experimental design	Experiments involve the manipulation of the independent variable by the investigator. The experimental treatment group is compared to a control. Simple experiments involve a single independent variable. A multifactorial experiment involves a combination of more than one independent variable or combination of treatments. The control of laboratory conditions allows simple experiments to be conducted more easily than in the field. Similarly, experiments conducted *in vivo* tend to be more complex than those *in vitro*. However, a drawback of a simple experiment is that its findings may not be applicable to a wider setting.	Consider an area of research and design a true experiment and an observational study. Contrast the strength of any conclusions that could be drawn from these types of study. Design and carry out a simple laboratory true experiment, such as an enzyme experiment, where confounding variables are tightly controlled. Design and carry out a field observational study, such as an environmental transect, where the independent variable is not under direct control and where confounding variables cannot be tightly controlled.

CONTENT	NOTES	CONTEXTS
(c) Experimental design (cont)	In some studies the investigator may wish to use groups that already exist, so there is no truly independent variable. These 'observational' studies are good at detecting correlation but, as they do not directly test the model, they are less useful for determining causation.	Carry out an observational study where the investigator groups the independent variable, such as a study of the effect of gender in a human study.
(d) Controls	The results of control groups are used for comparison with treatment results. The negative control group provides results in the absence of a treatment. A positive control is a treatment that is included to check that the system can detect a positive result when it occurs.	Design an experiment with positive and negative controls, such as a laboratory investigation using an enzyme.
(e) Sampling	Where it is impractical to measure every individual, a representative sample of the population is selected. The extent of the natural variation within a population determines the appropriate sample size. More variable populations require a larger sample size. A representative sample should share the same mean and the same degree of variation about the mean as the population as a whole. In random sampling, members of the population have an equal chance of being selected. In systematic sampling, members of a population are selected at regular intervals. In stratified sampling, the population is divided into categories that are then sampled proportionally.	Consider aspects of sampling in investigating heart rate in *Daphnia* or contraction of muscle due to ATP. Is variation in sample representative of natural variation in *Daphnia* or muscle tissue? Are the samples of *Daphnia* or muscle tissue independent? Condense data from non-independent samples (ie same *Daphnia*; tissue from same muscle). In ecological studies use random numbers to select quadrats for sampling. Establish sample size by determining a travelling mean or the cumulative total of species in quadrats. Use line or belt transects to systematically sample an environment. Use stratified sampling to sample habitats that are not uniform using a standard formula to calculate the number of samples from each area.

National Course specification: Course details (cont)

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CONTENT	NOTES	CONTEXTS
(f) Ensuring reliability	Variation in experimental results may be due to the reliability of measurement methods and/or inherent variation in the specimens.	
	The reliability of measuring instruments or procedures can be determined by repeated measurements or readings of an individual datum point. The variation observed indicates the precision of the measurement instrument or procedure but not necessarily its accuracy.	Determine the precision of a measuring procedure by repeated measurements and the accuracy of a measuring procedure by calibration against a known standard.
	The natural variation in the biological material being used can be determined by measuring a sample of individuals from the population. The mean of these repeated measurements will give an indication of the true value being measured.	Use measures of central tendency to measure the extent of natural variation in samples.
	Overall results can only be considered reliable if they can be achieved consistently. The experiment should be repeated as a whole to check the reliability of the results.	Check the consistency of results by repeating experiments, pooling results or reference to scientific literature.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

CONTENT	NOTES	CONTEXTS
3 Critical evaluation of biological research		
(a) Evaluating background information	Background information should be clear, relevant and unambiguous. A title should provide a succinct explanation of the study. A summary should outline the aims and findings of the study. The introduction should provide any information required to support methods, results and discussion. An introduction should explain why the study has been carried out and place the study in the context of existing understanding. Key points should be summarised and supporting and contradictory information identified. Several sources should be selected to support statements, and citations and references should be in a standard form. Decisions regarding basic selection of study methods and organisms should be covered, as should the aims and hypotheses. A method section should contain sufficient information to allow another investigator to repeat the work.	
(b) Evaluating experimental design	The validity and reliability of the experimental design should be evaluated. An experimental design that does not test the intended aim or hypothesis is invalid. Treatment effects should be compared to controls; the validity of an experiment may be compromised where factors other than the independent variable influence the value of the dependent variable. Selection bias may have prevented a representative sample being selected. Sample size may not be sufficient to decide without bias whether the modification to the independent variable has caused an effect in the dependent variable.	

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

CONTENT	NOTES	CONTEXTS
(c) Evaluating data analysis	In results, data should be presented in a clear, logical manner suitable for analysis. Data may be quantitative or qualitative depending on the variables investigated. Data are explored through the appropriate use of simple statistical procedures such as graphs, mean, median, mode, SD and range. Consideration should be given to the validity of outliers and anomalous results. Statistical tests are used to determine whether the results are likely or unlikely to have occurred by chance. A statistically significant result is one that is unlikely to be due to chance alone. Confidence intervals or error bars are used to indicate the variability of data around a mean. In general, if the treatment average differs from the control average sufficiently for their confidence intervals not to overlap then the data can be said to be different.	Compare variation in data in simple laboratory experiments on protein binding with that from complex ecological observational studies on biomes. Attempt to evaluate the validity of two methods investigating one scientific problem but producing conflicting results. Explore sets of data on energy flow in ecosystems using simple statistical procedures. Use a statistical test to confirm or refute significance of results of epidemiological study into disease.
(d) Evaluating conclusions	In evaluating conclusions, reference should be made to the aim of the study, the results obtained, and the validity and reliability of the experimental design. Any conclusion should refer back to a hypothesis. Consideration should be given as to whether significant results noted can be attributed to correlation or causation. Meaningful scientific discussion would include consideration of findings in the context of existing knowledge and the results of other investigations. Scientific writing should reveal an awareness of the contribution of scientific research to increasing scientific knowledge and to the social, economic and industrial life of the community.	Compare and evaluate a variety of discussions written about the same set of data on apoptosis in a cell culture. Discuss correlation and causation in the context of genome-wide association studies (GWAs).

National Course specification: Course details (cont)

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Assessment

To achieve the Course award the candidate must achieve the Units as well as pass the Course assessment. The candidate's grade is based on the Course assessment.

Assessment objectives

Candidates will be assessed on their knowledge and understanding of the content column and notes column in the tables for each Unit. The contents column in the tables for each Unit provides advice and suggests contexts and activities for learning and will not be liable for sampling in assessment.

Candidates will be assessed on their skills of scientific experimentation, investigation and enquiry and skills for learning, life and work. These skills should be developed in contexts related to the content and notes columns in the tables for each Unit and in carrying out the investigation that is part of the Unit *Investigative Biology*.

Advice on developing the capabilities associated with knowledge, understanding and skills is given in the section G*uidance on Learning and Teaching Approaches for this Course*.

Unit assessment

Cells and Proteins (Advanced Higher)
Organisms and Evolution (Advanced Higher)

Unit assessment will be based on a closed-book test with items based on the statement of standards for each Unit and a report of one experimental activity set in the context of the Unit based on the statement of standards. Only one report of an experimental activity is required to meet the Course specification for Advanced Higher Biology. This report can then be used as evidence of the statement of standards for the other Unit of the Course. The report can be in the format of a traditional lab report or an alternative such as a conference poster, scientific paper, Power Point presentation, video presentation or web page that covers the Performance Criteria.

Investigative Biology (Advanced Higher)

Unit assessment will be based on a closed-book test with items based on the statement of standards for each Unit and the candidate carrying out a biological investigation based on the statement of standards.

Further details about Unit assessment for this Course can be found in the Unit Specifications and the National Assessment Bank (NAB) materials.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

Course assessment

The external Course assessment will consist of an externally set examination worth approximately 80% of the marks and an investigation report worth approximately 20% of the marks. The external Course assessment will be based on the knowledge and understanding, skills of scientific experimentation, investigation and enquiry and skills for learning, life and work described in the Course content.

Examination

The examination will consist of one paper of 2 hours 30 minutes with a total of 90 marks. The paper will consist of two sections:

Section A

This section will contain 25 multiple-choice questions. Between 7 and 9 of these will test science skills and skills for learning, life and work; the remainder will test knowledge and understanding. Section A will have an allocation of 25 marks. Candidates will be expected to answer all the questions.

Section B

This section will contain structured questions (including data handling and experimental design items) and extended response questions with an allocation of 65 marks. Between 16 and 19 marks will test science skills and skills for learning, life and work; the remainder will test knowledge and understanding. Candidates will be expected to answer all the questions.

Further details of the Course assessment are given in the Course Assessment specification and in the Specimen Question Paper.

Complexity of data

The following advice is intended as general guidelines in setting the complexity of data to be used in science skills problem solving questions.

At Advanced Higher, typically three sources of data (text, tables, charts, keys, diagrams or graphs) should be provided from which the problem has to be solved. It is, however, recognised that extracting data from one source could be more demanding than extracting data from two sources for example, depending on the nature of the data.

Where there are not three separate sources of data, the provided data should normally have three to four patterns, trends, conditions, variables or sets of results from which information has to be selected and presented, or which have to be used as sources of evidence for conclusions, explanations, predictions or generalisations. The analysis of data should involve comparisons between two or more of these sets of data. Presented data could require account to be taken of central tendencies and significant differences. Data could be presented with error bars.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

The planning, designing and evaluation of experimental procedures should involve up to two of the following: purpose, one or two treatments, adequate controls, limitations of equipment, sources of error and possible improvements as appropriate.

Link between Unit and Course assessment/added value

Course assessment requires learners to demonstrate abilities beyond Unit assessment by:

- retaining knowledge and skills over an extended period of time
- integrating knowledge and understanding and skills from different Units
- applying knowledge, understanding and skills in contexts less familiar and more complex than in the component Units.

Investigation report

The investigation report is based on the investigation carried out in the Advanced Higher Unit *Investigative Biology*. The investigation must be the individual work of the candidate. Group work and joint investigations are not permitted. Candidates must not submit the same investigation for another SQA qualification.

Teachers/lecturers should offer advice and encouragement to candidates but avoid direction and excessive support. For example in discussing progress with candidates, teachers/lecturers should use open questions and refer to the principles of investigation learned in the Unit to assist candidates to reflect and review their own work. While candidates may need advice in the early stages of their investigation in identifying a suitable topic for investigation and in selecting an appropriate experimental design, as the investigation progresses teachers/lecturers should allow candidates to make more independent decisions in the analysis and evaluation of their results. Where candidates carry out their investigation outwith the centre or have access to external specialist advice the teacher/lecturer must ensure that the investigation is the individual work of the candidate. Any help received should be acknowledged and should not be excessive. Each candidate must sign the flyleaf accompanying the investigation report as a declaration that the report and the data in it have been produced by the candidate.

A total of 25 marks, representing approximately 20% of the total marks for the Course, are awarded for the investigation report. The report should be around 2,000 to 2,500 words in length excluding title page, contents page, tables, graphs, diagrams, calculations, references, acknowledgements and any appendices. The report must contain the following sections:

- title page
- contents page
- abstract/summary
- introduction
- procedures
- results
- discussion
- list of references.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

Detailed advice on the contents of the investigation report is given in *Advanced Higher Biology (revised) Candidate Investigation Guidance.* The investigation report will be externally assessed using the following assessment categories:

- Presentation (3 marks)
- Introduction (4 marks)
- Procedures (8 marks)
- Results (4 marks)
- Discussion (6 marks).

Grade

The grade awarded for the Course will depend on the marks obtained by the candidate (out of 115) for the examination and the investigation report. The certificate will record an award for overall attainment.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

Grade Descriptions at A and C

The candidate's grade will be based on the total score obtained from the Course assessment. The descriptions below indicate the nature of achievement required for an award at Grade C and A in the Course.

For an award at Grade C, candidates should be able to:

- retain knowledge and skills over an extended period of time
- integrate knowledge and understanding, science skills and skills for learning life and work acquired across component Units
- apply knowledge and understanding, science skills and skills for learning life and work in contexts similar to those in the component Units
- select, analyse and present relevant information collected through experimental, observational or survey work in the investigation
- write in a scientific manner which reveals the biological significance of the subject chosen for the investigation.

For an award at Grade A, candidates should be able to:

- retain an extensive range of knowledge and skills over an extended period of time
- integrate an extensive range of knowledge and understanding, science skills and skills for learning life and work acquired across component Units
- apply knowledge and understanding, science skills and skills for learning life and work in contexts less familiar and more complex than in the component Units
- show particular proficiency in selecting, analysing and presenting relevant information collected through experimental, observational or survey work in the investigation
- show particular proficiency in writing in a scientific manner which reveals the significance of the findings of the investigation by analysing and interpreting the results in a critical and scientific manner and demonstrating knowledge and understanding of the biological basis of the investigation.

Estimates and appeals

Detailed advice and guidance is issued to centres in the publication *Estimates, Absentees and Assessment Appeals: Guidance on Evidence Requirements.*

Estimates

In preparing estimates, evidence must take account of performance across the Course and must be judged against the Grade Descriptions. Further advice on the preparation of estimates is given in the Course Assessment specification.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

Appeals

Evidence to support appeals for the Course must show a sufficient breadth of coverage of the content, cover each of the seven skills areas and must relate to the Course grade descriptions at A and C. Approximately 30% of the assessment items in the evidence to support appeals should relate to the Course grade descriptions at A to ensure that learners who are graded at A are gaining marks in A grade items.

The evidence to support appeals should reflect the structure of the Course Assessment specification and the standards set out in the Specimen Question Paper. Centres must ensure that the instrument of assessment has not been seen previously by candidates.

An analysis of the evidence to support appeals showing the content and skills covered by assessment items along with marking schemes with cut off scores should be included with ***all*** evidence submitted in support of an appeal.

Quality Assurance

All National Courses are subject to external marking and/or verification. External Markers, visiting Examiners and Verifiers are trained by SQA to apply national standards.

The Units of all Courses are subject to internal verification and may also be chosen for external verification. This is to ensure that national standards are being applied across all subjects.

Courses may be assessed by a variety of methods. Where marking is undertaken by a trained Marker in their own time, Markers meetings are held to ensure that a consistent standard is applied. The work of all Markers is subject to scrutiny by the Principal Assessor.

To assist centres, External Assessment and Internal Assessment reports are published on SQA's website **www.sqa.org.uk**.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

Guidance on learning and teaching approaches for this Course

In delivering the Course, teachers should be building on learners' previously acquired knowledge and skills. Learners' experiences should include a variety of approaches to develop knowledge and understanding, science skills and skills for learning life and work. Scientific practical work is a major part of this Course and should be developed systematically throughout the Course. Laboratory and field techniques should be approached from both a theoretical and practical point of view. Learning experiences on these techniques could be taught as a sequence of lessons and/or built into the main teaching programme as appropriate. These laboratory and field study techniques may be used and/or further developed through the candidate's biology investigation. Investigative biology provides the opportunity to develop an understanding of the principles and processes of the scientific method. Learners should have the opportunity to critically evaluate scientific reports including commenting on experimental design and data analysis as well as evaluating conclusions. This will enhance learners' skills when it comes to carrying out their own investigation.

Practical experimental work is a key part of the learning about science and as such is an essential component of Biology Courses. In addition to being part of the way scientists work, practical work can fulfill a number of educational purposes including:

- Developing problem solving skills and analytical thinking
- Working collaboratively and thinking independently
- Illustrating concepts as an aid to understanding
- Developing experimental designs that are valid and reliable
- Testing hypotheses and drawing conclusions based on evidence
- Generating data for subsequent analysis
- Developing competence in practical techniques

Information and Communication Technology (ICT) makes a significant contribution to practical work in Biology in addition to the use of computers as a learning tool. Computer interfacing equipment can detect and record small changes in variables allowing experimental results to be recorded over short periods of time, completing experiments in class time. Results can also be displayed in real time helping to improve understanding. Data logging equipment and video cameras can be set up to record data and make observations over periods of time longer than a class lesson which can then be subsequently downloaded and viewed for analysis. The molecular evidence for evolution can be studied by using computer software to study DNA and protein sequence data.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

Knowledge and Understanding

The following capabilities related to demonstrating knowledge, applying knowledge and demonstrating understanding should be developed in Course work.

1 Demonstrating knowledge

Learners should be able to:

- Make accurate statements about biological organisms, relationships, processes, systems and cycles
- Use biological terms, symbols, abbreviations and Units correctly
- Describe the properties and structure and function of organisms
- Describe the properties of and relationships in biological processes, systems and cycles.

2 Applying knowledge

Learners should be able to:

- Use knowledge when interpreting biological information in textual, tabular or graphical forms
- Use a relationship, equation or formula to find a qualitative or quantitative solution to a biological problem
- Use existing knowledge in new situations
- Appreciate and understand the impact of science and technology on everyday life
- Make and justify personal decisions about things that involve biological science.

3 Demonstrating understanding

Learners should be able to:

- Demonstrate understanding of the properties and structure and function of organisms
- Demonstrate understanding of the properties of and relationships in biological processes, systems and cycles
- Give examples to illustrate a concept or relationship or to support an observation, hypothesis or point of view
- Explain an observation or phenomenon demonstrating understanding of the underlying concept, principle or theory
- Use knowledge to demonstrate understanding of cause and effect
- Combine knowledge with evidence from observation, experience and investigation to provide explanations, formulate hypotheses and make predictions about the effects of change on biological systems and processes
- Integrate knowledge in different areas of Biology.

National Course specification: Course details (cont)

COURSE Biology (revised) Advanced Higher

Skills of scientific experimentation, investigation and enquiry

Learners should acquire scientific skills through a series of learning experiences, investigations and experimental work set in the contexts described in the content statements and supplementary notes of the Course specification. These skills should be developed throughout the Course using a variety of case studies, practical activities and other learning experiences as appropriate. Some activities and experiences will lend themselves to developing particular skills more than others. For example some practical activities will be particularly suitable for developing planning and designing skills, some for presenting and analysing data skills and others for the skill of drawing conclusions. In selecting appropriate activities and experiences teachers and lecturers should identify which skills are best developed in each activity to ensure the progressive development of all skills and to support candidates' learning. Further details on the skills that should be developed in Course work are given below.

COURSE Biology (revised) Advanced Higher

1 Selecting Information

Select and analyse relevant information from texts, tables, charts, keys, graphs and/or diagrams.

The study of Biology involves dealing with written and visual information. Candidates will often deal with more complex information than they can produce.

Learners should be able to:

- work with quantitative and qualitative data, discrete and continuous data and sampled data
- deal with experimental data presented in tables, pie and bar charts, line graphs, lines of best fit, graphs with semi logarithmic scales, graphs with error bars and information presented as box plots
- analyse and interpret typically three interconnected tables, charts, keys, graphs or diagrams or a single source of graphical information with three to four patterns, trends, conditions, variables or sets of results
- deal with statistical concepts such as the mean, range and standard deviation of data and statistically significant differences (as shown by error bars in graphs and plus and minus values in tables of results)
- deal with text to analyse its content, select appropriate information, identify and evaluate evidence, explain relationships, draw conclusions and display related knowledge
- use computers and software applications to search and retrieve relevant information.

2 Presenting Information

Present information appropriately in a variety of forms, including summaries and extended text, flow charts, keys, diagrams, tables and/or graphs.

(a) Representing data

Learners should be able to:

- present variables from experimental or other data in an appropriate form including tables, charts, keys, graphs and diagrams
- distinguish between dependent and independent variables.

(b) Communication

Learners should be able to:

- select, organise and present relevant information, including presenting alternative points of view, on a biological issue
- produce scientific reports which describe experimental procedures, record relevant observations and measurements, analyse and present results, draw conclusions and evaluate procedures with supporting argument.

- produce extended text presenting relevant ideas clearly, coherently and logically using specialist vocabulary where appropriate.
- use word processing and graphics packages, spreadsheets and other data handling software.

(c) Oral communication

Through discussion and presentations learners should be able to:

- convey information clearly and logically using specialist vocabulary where appropriate
- use images including charts, models, graphs, diagrams, illustrations or video in conveying information
- respond to others by answering questions, clarifying points, contributing points of view and asking questions to clarify or explore in greater depth.

3 Processing Information

Process information accurately using calculations where appropriate.

Learners should be able to:

- perform calculations involving whole numbers, decimals and fractions
- calculate ratios and percentages including percentage increase and decrease
- round answers to an appropriate degree of accuracy (eg to two decimal places or three significant figures)
- deal with a range of Units in accordance with Society of Biology recommendations. Candidates will be expected to be able to convert between, eg μg and mg
- deal with calculations involving negative numbers, numbers represented by symbols and scientific notation
- work with data to find the mean and range of the data
- calculate genetic ratios based on probability
- substitute numerical values into equations and changing the subject of an equation
- use software packages to carry out statistical and other data handling processes.

4 Planning, Designing and Carrying Out

Plan, design and carry out experimental procedures to test given hypotheses or to illustrate particular effects. This could include identification of variables, controls and measurements or observations required.

(a) Planning and designing

Learners should be able to:

- state the aim of an investigation
- suggest a hypotheses for investigation based on observation of biological phenomena
- plan experimental procedures and select appropriate techniques
- suggest suitable variables that could be investigated in a given experimental set up
- identify dependent and independent variables in an investigation

- decide on the experimental designs required to ensure the validity of experimental procedures
- decide on the measurements and observations required to ensure reliable results
- modify procedures in the light of experience.

(b) Carrying Out

Learners should be able to:

- identify component tasks in practical work and plan a procedure (to include timings and allocation of tasks where appropriate)
- identify, obtain and organise the resources required for practical work
- carry out work in a methodical and organised way with due regard for safety and with consideration for the well-being of organisms and the environment where appropriate
- follow procedures accurately
- make and record observations and measurements accurately
- capture experimental data electronically using a range of devices
- modify procedures and respond to sources of error.

5 Evaluating

Evaluate experimental procedures by commenting on the purpose or approach, the suitability and effectiveness of procedures, the control of variables, the limitations of equipment, possible sources of error and/or suggestions for improvement.

Learners should be able to:

- identify and comment on variables that are not controlled in experimental situations and distinguish between dependent and independent variables
- identify sources of error in measurements and observations
- identify and comment on the reliability of results
- identify and comment on the validity of experimental designs
- suggest possible improvements to experimental set ups
- use observations and collected data to make suggestions for further work.

6 Drawing conclusions

Draw valid conclusions and give explanations supported by evidence or justification. Conclusions should include reference to the aim of the experiment, overall pattern to readings or observations, trends in results or comment on the connection between variables and controls.

Learners should be able to:

- analyse and interpret experimental data to select relevant information from which conclusions can be drawn
- state the results of the investigation
- draw conclusions on the relationships between the dependent and independent variables
- take account of controls when drawing conclusions
- analyse and interpret experimental data to identify patterns, trends and rates of change.

7 Making predictions and generalisations

Make predictions and generalisations based on available evidence.

Learners should be able to:

- predict the Outcome in experimental situations from supplied information
- make generalisations from a range of biological information
- use modeling and simulation software to test predictions and answer questions related to biological and experimental phenomena
- Use evidence to support a personal decision or point of view on a current scientific, technological, environmental or health issue.

Skills for learning, life and work

As a result of their study of Biology learners should have the opportunity to:

- Use their literacy, communication and numeracy skills to demonstrate their knowledge and understanding of Biology
- Solve problems by thinking creatively, working with others and planning and managing tasks related to biological laboratory and field work
- Develop competence in the use of laboratory and fieldwork equipment and the use of information and communication technology
- Identify hazards, assess their risk in different situations and suggest control measures
- Make ethical decisions based on researching relevant information and a consideration of the consequences for different courses of action.

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**

History of changes

Version	Description of change	Date

Additional copies of this Unit specification can be purchased from the Scottish Qualifications Authority. Please contact the Business Development and Customer Support team, telephone 0303 333 0330.

National Unit specification: general information

Unit title: Cells and Proteins (SCQF level 7)

Unit code: H0AK 13

Superclass: RH

Publication date: December 2011

Source: Scottish Qualifications Authority

Version: 01

Summary

This Unit is a mandatory Unit of the Biology (revised) Advanced Higher Course and has been designed to be taken as part of that Course. It can also be taken as a free-standing Unit.

This Unit seeks to develop knowledge and understanding of biology laboratory techniques and of the role proteins play in the structure and functioning of cells and organisms.

Successful learners will be able to describe the use of laboratory techniques. They will be able to describe and explain the role of proteins in cells and organisms and apply their knowledge in new situations and when interpreting related biological information. They will be able to plan, design and carry out practical work; collect, analyse and present scientific data and information; draw conclusions and make predictions and generalisations based on scientific evidence. They will be able to evaluate scientific work and write a scientific report on an experimental activity related to cells and proteins that they have carried out.

This Unit is suitable for learners who have studied cell biology as part of a Course or Unit at SCQF level 6.

Outcomes

1 Demonstrate Knowledge and Understanding related to cells and proteins and associated laboratory techniques.
2 Solve problems related to cells and proteins using scientific skills.
3 Collect and analyse information related to cells and proteins by experiment.

General information (cont)

Recommended entry

While entry is at the discretion of the centre, candidates would normally be expected to have attained a Biology, Biotechnology or Human Biology National Qualification at SCQF level 6 or its equivalent.

Credit points and level

1 National Unit credit at SCQF level 7: (8 SCQF credit points at SCQF level 7*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Core Skills

Opportunities to develop aspects of Core Skills are highlighted in the Support Notes of this Unit specification.

There is no automatic certification of Core Skills or Core Skill components in this Unit.

National Unit specification: statement of standards

Unit title: Cells and Proteins (SCQF level 7)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Outcome 1

Demonstrate Knowledge and Understanding related to cells and proteins and associated laboratory techniques.

Performance Criteria

(a) Make accurate statements and give clear descriptions about cells and proteins and the laboratory techniques used to study them.
(b) Apply relevant knowledge of cells and proteins in new situations and appreciate its significance when interpreting biological information.
(c) Explain the biology of cells and proteins with reasons or supporting evidence.

Outcome 2

Solve problems related to cells and proteins using scientific skills.

Performance Criteria

(a) Select and present relevant information in an appropriate format.
(b) Process information accurately using calculations where appropriate.
(c) Draw valid conclusions and give explanations supported by evidence.
(d) Plan, design and evaluate experimental procedures appropriately.
(e) Make predictions and generalisations based on evidence.

Outcome 3

Collect and analyse information related to cells and proteins by experiment.

Performance Criteria

(a) Participate actively in the collection of information by experiment.
(b) Describe the experimental procedures accurately.
(c) Record relevant measurements and observations in an appropriate format.
(d) Analyse and present the recorded experimental information in an appropriate format.
(e) Draw valid conclusions.
(f) Evaluate the experimental procedures with supporting argument.

National Unit specification: statement of standards (cont)

Unit title: Cells and Proteins (SCQF level 7)

Evidence Requirements for this Unit

Evidence is required to demonstrate that learners have achieved all Outcomes and Performance Criteria.

The standard to be applied and the breadth of coverage are illustrated in the National Assessment Bank items available for this Unit. If a centre wishes to design its own assessments for this Unit they should be of a comparable standard.

Written and/or oral evidence of an appropriate level of achievement must be generated from a closed-book instrument of assessment under controlled conditions covering the Performance Criteria for Outcome 1 and Outcome 2 set in the context of laboratory techniques and the structure, binding and conformational changes of proteins and their role in; membranes, detecting and amplifying environmental stimuli, communication within multicellular organisms and in controlling cell division, with a time limit of 45 minutes.

A report of one experiment is required covering the Performance Criteria for Outcome 3 set in the context of Cells and Proteins. The report can be in the format of a traditional laboratory report or an alternative that covers the Performance Criteria for the Unit such as conference poster, scientific paper, Power Point presentation, video presentation or web page.

The report must be the individual work of the candidate derived from active participation in an experiment in which the candidate: plans the experiment; decides how it is managed; identifies and obtains the necessary resources, some of which must be unfamiliar; and carries out the experiment. Depending on the activity, the collection of the information may be group work.

Evidence submitted in support of attainment of PC (d) must be in the format of a table or graph(s) as appropriate. Conclusions drawn must be justified by reference to supporting evidence and comment on trends or patterns and/or connections between variables and controls.

The evaluation should cover all stages of the experiment, including the initial analysis of the situation and planning and organising the experimental procedure. In carrying out the experiment candidates should consider modifying procedures and respond to sources of error.

National Unit specification: support notes

Unit title: Cells and Proteins (SCQF level 7)

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

A summary of the guidance on the content and context for this Unit is provided below. Further guidance on the content and context for this Unit is provided in the Course content tables for Cells and Proteins in the National Course specification for Biology (revised) Advanced Higher. The contents column in these tables provides contexts in which the knowledge and understanding and skills for this Unit can be developed and are not liable for assessment although they may provide contexts for assessment items.

1 Laboratory techniques for biologists

- (a) Health and safety
- (b) Liquids and solutions
- (c) Separation techniques
- (d) Antibody techniques
- (e) Microscopy
- (f) Aseptic technique and cell culture

2 Proteins

- (a) Proteomics
- (b) Protein structure, binding and conformational change
    - (i) Amino acid sequence determines protein structure
    - (ii) Hydrophobic and hydrophilic interactions influence the location of cellular proteins
    - (iii) Binding to ligands
    - (iv) Binding changes the conformation of a protein
    - (v) Reversible binding of phosphate and control of conformation
- (c) Membrane proteins
    - (i) Movement of molecules across membranes
    - (ii) Signal transduction
    - (iii) Ion transport pumps and generation of ion gradients
    - (iv) Ion channels and nerve transmission
- (d) Detecting and amplifying an environmental stimulus
    - (i) Photoreceptor protein systems
- (e) Communication within multicellular organisms
    - (i) Coordination
    - (ii) Hydrophobic signals and control of transcription
    - (iii) Hydrophilic signals and transduction
- (f) Protein control of cell division
    - (i) Cell division requires the remodelling of the cell’s cytoskeleton
    - (ii) The cell cycle
    - (iii) Control of the cell cycle
    - (iv) Control of apoptosis

National Unit specification: support notes (cont)

Unit title: Cells and Proteins (SCQF level 7)

Guidance on learning and teaching approaches for this Unit

Guidance on learning and teaching approaches for this Unit are provided in the guidance on learning and teaching approaches in the Course specification for Biology (revised) Advanced Higher.

Opportunities for developing Core Skills

In this Unit candidates will develop skills that are valuable for personal development, future learning and employability. Opportunities to develop Problem Solving and Using Graphical Information occur in Outcome 2 and Outcome 3. The guidance on learning and teaching approaches for this Unit provided in the Course specification for Biology (revised) Advanced Higher highlights opportunities to develop Using Number when processing information and to develop Oral and Written Communication when presenting information. In addition it highlights opportunities to develop *Working with Others* when carrying out practical experimental work and to develop Using Information Technology in practical experimental work and for data analysis.

Guidance on approaches to assessment for this Unit

A holistic approach is taken to assessment, ie Outcomes 1 and 2 are assessed by an integrated end of Unit test with questions covering all the Performance Criteria for knowledge and understanding and problem solving.

Outcome 1

Test items should be constructed to allow learners to meet all of the Performance Criteria in the context of laboratory techniques and the structure, binding and conformational changes of proteins and their role in: movement across membranes, detecting and amplifying environmental stimuli, communication in multicellular organisms and in controlling cell division.

Outcome 2

Test items should be constructed to allow learners to generate evidence relating to the Performance Criteria as follows:

(a) Selecting and presenting information:
- ♦ sources of information could include: texts, tables, charts, graphs and/or diagrams
- ♦ formats of presentation could include: written summaries, extended writing, tables and/or graphs.

(b) Calculations could include: percentages, averages, ratios. Significant figures, scientific notation and units should be used appropriately.

(c) Conclusions drawn should include some justification, and explanations should be supported by evidence. Conclusions could contain a comment on trends or patterns and/or connections between variables and controls.

National Unit specification: support notes (cont)

Unit title: Cells and Proteins (SCQF level 7)

(d) Learners could plan and design procedures to test given hypotheses or to illustrate particular effects. This could include identification of variables, controls and measurements or observations required. The evaluation of given experimental procedures may include situations which are unfamiliar to the candidate and could test the candidate's ability to comment on the purpose of approach or the suitability of given experimental procedures. Learners could comment on the limitations of the set-up, apparatus, suggested measurements or observations, limitations of equipment, appropriateness of controls, sources of error and possible improvements.

(e) Learners could make predictions and generalisations from given experimental results or, given situations, predict what the results might be.

Outcome 3

Type of experimental activity

The teacher/lecturer should ensure that the experimental activity to be undertaken in connection with Outcome 3 affords opportunity for the learner to demonstrate the ability to undertake the planning and organising of an experimental activity at an appropriate level of demand. The activity must relate to the Course content and candidates should be made aware of the range of skills which must be demonstrated to ensure attainment of Outcome 3.

Assessment of Outcome 3

Learners are only required to produce one report for Outcome 3 in relation to the contents and notes specified for Biology (revised) Advanced Higher. This report can then be used as evidence for Outcome 3 for the other Unit of the Course.

In relation to PC (a), the teacher/lecturer checks by observation that the learner participates in the collection of the experimental information by playing an active part in planning the experiment, deciding how it will be managed, identifying and obtaining resources (some of which must be unfamiliar to the candidate), and carrying out the experiment.

Unit title: Cells and Proteins (SCQF level 7)

Learners should provide a report with an appropriate title. The report should relate to the Performance Criteria as follows:

(b) The experimental procedures are described accurately.	A clear statement of the aim of the experiment. A few brief concise sentences including as appropriate: ♦ a labelled diagram or brief description of apparatus or ♦ instruments used ♦ how the independent variable was altered ♦ control measure used ♦ how measurements were taken or observations made. There is no need for a detailed description. The use of the impersonal passive voice is to be encouraged as an example of good practice but this is not mandatory for meeting the Performance Criteria.
(c) Relevant measurements and observations are recorded in an appropriate format.	Readings or observations (raw data) must be recorded in a clear table with correct headings, appropriate units and results/readings entered correctly.
(d) Recorded experimental information is analysed and presented in an appropriate format.	Data should be analysed and presented in tabular, graphical format or as a scatter diagram or equivalent, as appropriate: ♦ For a tabular presentation this may be an extension of the table used for PC (c) above, and must include: suitable headings and units showing averages or other appropriate computations ♦ For a graphical presentation this must include: data presented as a histogram, bar chart, connected points or line of best fit as appropriate, with suitable scales and axes labelled with variable and units and with data correctly plotted.
(e) Conclusions drawn are valid.	Conclusions should use evidence from the experiment and relate back to the aim of the experiment. At least one of the following should be included: ♦ overall pattern to readings or observations (raw data) ♦ trends in analysed information or results ♦ connection between variables and controls.
(f) The experimental procedures are evaluated with supporting argument.	The evaluation could cover all stages of the activity including preparing for the activity, analysis of the activity and the results of the activity. The evaluation must include supporting argument in at least one of the following: ♦ effectiveness of procedures ♦ control of variables ♦ limitations of equipment ♦ possible sources of error ♦ possible improvements.

National Unit specification: support notes (cont)

Unit title: Cells and Proteins (SCQF level 7)

The bullet points under each Performance Criterion give an indication of what should be addressed to achieve a pass. The relevance of the bullet points will vary according to the experiment. These bullet points are intended as helpful guidance. The decision of pass or fail is to be made by the professional judgment of the presenting centre (subject to external verification) against the Performance Criteria. It is appropriate to support candidates in producing a report to meet the Performance Criteria. Re-drafting of a report after necessary supportive criticism is to be encouraged both as part of the learning and teaching process and to produce evidence for assessment. Redrafting and resubmission is only required for the specific Performance Criterion identified in need of further attention ie the entire report does not need to be rewritten.

Conditions required to complete the report

Learners may complete their work outwith class time provided reasonable measures are taken to ensure that the report is the individual work of the candidate. Teachers and lecturers may wish candidates to write up reports under their direct supervision so that they can provide appropriate advice and support. However, they may feel confident that any redrafting required need not be undertaken under such close supervision as it will be evident in the candidate's response that it is his or her unaided work. Under such circumstances it would be acceptable for such redrafting to take place outwith class time.

Use of IT

Learners may, if they wish, present their reports in a word-processed format. Learners may use Excel (or any other suitable data analysis software) when tackling Outcome 3. However, candidates must not be given a spreadsheet with pre-prepared column headings nor formulae, as they are being assessed on their ability to enter quantities and units into a table and to make decisions about appropriate scales and labels on graph axes. The use of clip art or images captured by digital camera may also be used in recording details of experimental methods.

Transfer of evidence

Learners may transfer evidence for Outcome 3 from one level to the one below provided the experiment is in the context of the Course concerned. Learners who are repeating a Course may carry forward evidence of an appropriate standard, generated in a previous year.

Opportunities for the use of e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or e-checklists. Centres which wish to use e-assessment must ensure that the national standard is applied to all candidate evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. Further advice is available in *SQA Guidelines on Online Assessment for Further Education (AA1641, March 2003), SQA Guidelines on e-assessment for Schools (BD2625, June 2005)*.

National Unit specification: support notes (cont)

Unit title: Cells and Proteins (SCQF level 7)

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**

History of changes

Version	Description of change	Date

Additional copies of this Unit specification can be purchased from the Scottish Qualifications Authority. Please contact the Customer Contact Centre, telephone 0845 279 1000.

National Unit specification: general information

Unit title: Organisms and Evolution (SCQF level 7)

Unit code: H0AL 13

Superclass: RH

Publication date: December 2011

Source: Scottish Qualifications Authority

Version: 01

Summary

This Unit is a mandatory Unit of the Biology (revised) Advanced Higher Course and has been designed to be taken as part of that Course. It can also be taken as a free-standing Unit.

This Unit seeks to develop knowledge and understanding of biology field techniques and the role of sexual reproduction and parasitism in the evolution of organisms.

Successful learners will be able to describe the use of biology field techniques. They will be able to describe and explain the role of sexual reproduction and parasitism in evolution and apply their knowledge in new situations and when interpreting related biological information. They will be able to plan, design and carry out practical work; collect, analyse and present scientific data and information; draw conclusions and make predictions and generalisations based on scientific evidence. They will be able to evaluate scientific work and write a scientific report on an experimental activity related to evolution and organisms that they have carried out.

This Unit is suitable for learners who have studied genomics, inheritance, parasitism and disease as part of a Course or Unit at SCQF level 6.

Outcomes

1 Demonstrate Knowledge and Understanding related to organisms and evolution and associated field techniques.
2 Solve problems related to cells and proteins using scientific skills.
3 Collect and analyse information related to cells and proteins by experiment.

General information (cont)

Recommended entry

While entry is at the discretion of the centre, candidates would normally be expected to have attained a Biology, Biotechnology or Human Biology National Qualification at SCQF level 6 or its equivalent.

Credit points and level

1 National Unit credit at SCQF level 7: (8 SCQF credit points at SCQF level 7*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Core Skills

Opportunities to develop aspects of Core Skills are highlighted in the Support Notes of this Unit specification.

There is no automatic certification of Core Skills or Core Skill components in this Unit.

National Unit specification: statement of standards

Unit title: Organisms and Evolution (SCQF level 7)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Outcome 1

Demonstrate Knowledge and Understanding related to evolution and organisms and associated field techniques.

Performance Criteria

(a) Make accurate statements and give clear descriptions about organisms and evolution and the field techniques used to study them.
(b) Apply relevant knowledge of organisms and evolution in new situations and appreciate its significance when interpreting biological information.
(c) Explain the biology of organisms and evolution with reasons or supporting evidence.

Outcome 2

Solve problems related to organisms and evolution using scientific skills.

Performance Criteria

(a) Select and present relevant information in an appropriate format.
(b) Process information accurately using calculations where appropriate.
(c) Draw valid conclusions and give explanations supported by evidence.
(d) Plan, design and evaluate experimental procedures appropriately.
(e) Make predictions and generalisations based on evidence.

Outcome 3

Collect and analyse information related to organisms and evolution by experiment.

Performance Criteria

(a) Participate actively in the collection of information by experiment.
(b) Describe the experimental procedures accurately.
(c) Record relevant measurements and observations in an appropriate format.
(d) Analyse and present the recorded experimental information in an appropriate format.
(e) Draw valid conclusions.
(f) Evaluate the experimental procedures with supporting argument.

National Unit specification: statement of standards (cont)

Unit title: Organisms and Evolution (SCQF level 7)

Evidence Requirements for this Unit

Evidence is required to demonstrate that learners have achieved all Outcomes and Performance Criteria.

The standard to be applied and the breadth of coverage are illustrated in the National Assessment Bank items available for this Unit. If a centre wishes to design its own assessments for this Unit they should be of a comparable standard.

Written and/or oral Evidence of an appropriate level of achievement must be generated from a closed-book instrument of assessment under controlled conditions covering the Performance Criteria for Outcome 1 and Outcome 2 set in the context of field techniques and the role of evolution in variation and sexual reproduction, sex and behaviour and in parasitism, with a time limit of 45 minutes.

A report of one experiment is required covering the Performance Criteria for Outcome 3 set in the context of Organisms and Evolution. The report can be in the format of a traditional laboratory report or an alternative that covers the Performance Criteria for the Unit such as conference poster, scientific paper, Power Point presentation, video presentation or web page.

The report must be the individual work of the candidate derived from active participation in an experiment in which the candidate plans the experiment; decides how it is managed; identifies and obtains the necessary resources, some of which must be unfamiliar; and carries out the experiment. Depending on the activity, the collection of the information may be group work.

Evidence submitted in support of attainment of PC (d) must be in the format of a table or graph(s) as appropriate. Conclusions drawn must be justified by reference to supporting evidence and comment on trends or patterns and/or connections between variables and controls.

The evaluation should cover all stages of the experiment, including the initial analysis of the situation and planning and organising the experimental procedure. In carrying out the experiment candidates should consider modifying procedures and respond to sources of error.

National Unit specification: support notes

Unit title: Organisms and Evolution (SCQF level 7)

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

A summary of the guidance on the content and context for this Unit is provided below. Further guidance on the content and context for this Unit is provided in the Course content tables for Organisms and Evolution in the National Course specification for Biology (revised) Advanced Higher. The contents column in these tables provides contexts in which the knowledge and understanding and skills for this Unit can be developed and are not liable for assessment although they may provide contexts for assessment items.

1 Field techniques for biologists
- (a) Health and safety
- (b) Sampling wild organisms
- (c) Identification and taxonomy
- (d) Monitoring populations
- (e) Measuring and recording animal behaviour

2 Organisms
- (a) Evolution
  - (i) Drift and selection
  - (ii) Rate of evolution
  - (iii) Co-evolution and the Red Queen
- (b) Variation and sexual reproduction
  - (i) Costs and benefits of reproduction
  - (ii) Meiosis forms variable gametes
  - (iii) Sex determination
- (c) Sex and behaviour
  - (i) Sexual investment
  - (ii) Courtship
- (d) Parasitism
  - (i) The parasite niche
  - (ii) Transmission and virulence
  - (iii) Immune response to parasites
  - (iv) Macroparasitic life cycles
  - (v) Microparasites
  - (vi) Challenges in treatment and control

Guidance on learning and teaching approaches for this Unit

Guidance on learning and teaching approaches for this Unit are provided in the guidance on learning and teaching approaches in the Course specification for Biology (revised) Advanced Higher.

Unit title: Organisms and Evolution (SCQF level 7)

Opportunities for developing Core Skills

In this Unit candidates will develop skills that are valuable for personal development, future learning and employability. Opportunities to develop Problem Solving and Using Graphical Information occur in Outcome 2 and Outcome 3. The guidance on learning and teaching approaches for this Unit provided in the Course specification for Biology (revised) Advanced Higher highlights opportunities to develop Using Number when processing information and to develop Oral and Written Communication when presenting information. In addition it highlights opportunities to develop *Working with Others* when carrying out practical experimental work and to develop Using Information Technology in practical experimental work and for data analysis.

Guidance on approaches to assessment for this Unit

A holistic approach is taken to assessment, ie Outcomes 1 and 2 are assessed by an integrated end of Unit test with questions covering all the Performance Criteria for knowledge and understanding and problem solving.

Outcome 1

Test items should be constructed to allow learners to meet all of the Performance Criteria in the context of field techniques and the role of evolution in variation and sexual reproduction, sex and behaviour and in parasitism.

Outcome 2

Test items should be constructed to allow learners to generate evidence relating to the Performance Criteria as follows:

(a) Selecting and presenting information:
  - sources of information could include: texts, tables, charts, graphs and diagrams
  - formats of presentation could include: written summaries, extended writing, tables and graphs.

(b) Calculations could include: percentages, averages, ratios. Significant figures, scientific notation and units should be used appropriately.

(c) Conclusions drawn should include some justification, and explanations should be reported by evidence. Conclusions could contain a comment on trends or patterns and/or connections between variables and controls.

(d) Learners could plan and design procedures to test given hypotheses or to illustrate particular effects. This could include identification of variables, controls and measurements or observations required. The evaluation of given experimental procedures may include situations which are unfamiliar to the candidate and could test the candidate’s ability to comment on the purpose of approach or the suitability of given experimental procedures. Learners could comment on the limitations of the set-up, apparatus, suggested measurements or observations, limitations of equipment, appropriateness of controls, sources of error and possible improvements.

(e) Learners could make predictions and generalisations from given experimental results or, given situations, predict what the results might be.

National Unit specification: support notes (cont)

Unit title: Organisms and Evolution (SCQF level 7)

Outcome 3

Type of experimental activity

The teacher/lecturer should ensure that the experimental activity to be undertaken in connection with Outcome 3 affords opportunity for the learner to demonstrate the ability to undertake the planning and organising of an experimental activity at an appropriate level of demand. The activity must relate to the Course content and candidates should be made aware of the range of skills which must be demonstrated to ensure attainment of Outcome 3.

Assessment of Outcome 3

Learners are only required to produce one report for Outcome 3 in relation to the contents and notes specified for Biology (revised) Advanced Higher. This report can then be used as evidence for Outcome 3 for the other Unit of the Course.

In relation to PC (a), the teacher/lecturer checks by observation that the learner participates in the collection of the experimental information by playing an active part in planning the experiment, deciding how it will be managed, identifying and obtaining resources (some of which must be unfamiliar to the candidate), and carrying out the experiment.

Learners should provide a report with an appropriate title. The report should relate to the Performance Criteria as follows:

(b) The experimental procedures are described accurately.	A clear statement of the aim of the experiment. A few brief concise sentences including as appropriate: ♦ a labelled diagram or brief description of apparatus or instruments used ♦ how the independent variable was altered ♦ control measure used ♦ how measurements were taken or observations made. There is no need for a detailed description. The use of the impersonal passive voice is to be encouraged as an example of good practice but this is not mandatory for meeting the Performance Criteria.
(c) Relevant measurements and observations are recorded in an appropriate format.	Readings or observations (raw data) must be recorded in a clear table with correct headings, appropriate units and results/readings entered correctly.

Unit title: Organisms and Evolution (SCQF level 7)

(d) Recorded experimental information is analysed and presented in an appropriate format.	Data should be analysed and presented in tabular, graphical format or as a scatter diagram or equivalent, as appropriate: ♦ For a tabular presentation this may be an extension of the table used for PC (c) above, and must include: suitable headings and units showing averages or other appropriate computations ♦ For a graphical presentation this must include: data presented as a histogram, bar chart, connected points or line of best fit as appropriate, with suitable scales and axes labelled with variable and units and with data correctly plotted.
(e) Conclusions drawn are valid.	Conclusions should use evidence from the experiment and relate back to the aim of the experiment. At least one of the following should be included: ♦ overall pattern to readings or observations (raw data) ♦ trends in analysed information or results ♦ connection between variables and controls.
(f) The experimental procedures are evaluated with supporting argument.	The evaluation could cover all stages of the activity including preparing for the activity, analysis of the activity and the results of the activity. The evaluation must include supporting argument in at least one of the following: ♦ effectiveness of procedures ♦ control of variables ♦ limitations of equipment ♦ possible sources of error ♦ possible improvements.

The bullet points under each Performance Criterion give an indication of what should be addressed to achieve a pass. The relevance of the bullet points will vary according to the experiment. These bullet points are intended as helpful guidance. The decision of pass or fail is to be made by the professional judgment of the presenting centre (subject to external verification) against the Performance Criteria. It is appropriate to support candidates in producing a report to meet the Performance Criteria. Re-drafting of a report after necessary supportive criticism is to be encouraged both as part of the learning and teaching process and to produce evidence for assessment. Redrafting and resubmission is only required for the specific Performance Criterion identified in need of further attention ie the entire report does not need to be rewritten.

Conditions required to complete the report

Learners may complete their work outwith class time provided reasonable measures are taken to ensure that the report is the individual work of the candidate. Teachers and lecturers may wish candidates to write up reports under their direct supervision so that they can provide appropriate advice and support. However, they may feel confident that any redrafting required need not be undertaken under such close supervision as it will be evident in the candidate's response that it is his or her unaided work. Under such circumstances it would be acceptable for such redrafting to take place outwith class time.

Unit title: Organisms and Evolution (SCQF level 7)

Use of IT

Learners may, if they wish, present their reports in a word-processed format. Learners may use Excel (or any other suitable data analysis software) when tackling Outcome 3. However, candidates must not be given a spreadsheet with pre-prepared column headings nor formulae, as they are being assessed on their ability to enter quantities and units into a table and to make decisions about appropriate scales and labels on graph axes. The use of clip art or images captured by digital camera may also be used in recording details of experimental methods.

Transfer of evidence

Learners may transfer evidence for Outcome 3 from one level to the one below provided the experiment is in the context of the Course concerned. Learners who are repeating a Course may carry forward evidence of an appropriate standard, generated in a previous year.

Opportunities for the use of e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or e-checklists. Centres which wish to use e-assessment must ensure that the national standard is applied to all candidate evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. Further advice is available in *SQA Guidelines on Online Assessment for Further Education (AA1641, March 2003), SQA Guidelines on e-assessment for Schools (BD2625, June 2005)*.

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History of changes

Version	Description of change	Date

Additional copies of this Unit specification can be purchased from the Scottish Qualifications Authority. Please contact the Customer Contact Centre, telephone 0845 279 1000.

National Unit Specification: general information

Unit title: Investigative Biology (SCQF level 7)

Unit code: H0AM 13

Superclass: RH

Publication date: December 2011

Source: Scottish Qualifications Authority

Version: 01

Summary

This Unit is a mandatory Unit of the Biology (revised) Advanced Higher Course and has been designed to be taken as part of that Course. It can also be taken as a free-standing Unit.

This Unit aims to develop knowledge and understanding of the principles and practice of scientific investigative work in biology and the skills to analyse and evaluate biological research. Based on this knowledge, understanding and skills candidates will be able to carry out their own biological investigation. The biological investigation will develop candidates' skills to plan and design experiments appropriate to the aim of the investigation and to consider ethical issues of experimentation and any potential hazards. The collection of experimental data will provide opportunity to develop planning and organising skills. Candidates who complete this Unit will have acquired skills which will be useful for future studies in Higher/Further Education and/or for a career in which biology/biological sciences may be used.

This Unit is suitable for candidates who have studied biology, biotechnology or human biology as part of a Course or Unit at SCQF level 6.

Outcomes

1 Demonstrate Knowledge and Understanding of biological research and experimental design.
2 Analyse and evaluate reports of biological research.
3 Carry out a biological investigation.

Recommended entry

While entry is at the discretion of the centre, candidates would normally be expected to have attained a Biology, Biotechnology or Human Biology National Qualification at SCQF level 6 or its equivalent.

General information (cont)

Credit value

1 National Unit credit at SCQF level 7: (8 SCQF credit points at SCQF level 7*).

*SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.

Core Skills

Opportunities to develop aspects of Core Skills are highlighted in the Support Notes of this Unit specification.

There is no automatic certification of Core Skills or Core Skill component in this Unit.

National Unit specification: statement of standards

Unit title: Investigative Biology (SCQF level 7)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit Specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Outcome 1

Demonstrate Knowledge and Understanding of biological research and experimental design.

Performance Criteria

(a) The scientific method is described correctly in terms of the scientific cycle, ethics, pilot studies and the use of literature to support findings.
(b) Experimental methods are explained correctly with reference to appropriate variables, controls, sampling and reliability in experimental designs.

Outcome 2

Analyse and evaluate reports of biological research.

Performance Criteria

(a) The background information is evaluated in terms of a clear summary, relevant explanations of the underlying science and correct citation of appropriate references.
(b) The experimental design is analysed in terms of validity and reliability.
(c) The analysis and presentation of the data is evaluated in terms of the appropriate use of tables, graphs and statistical analysis to show findings.
(d) The conclusions are evaluated taking into account the aim of the study, the results obtained and the validity and reliability of the experimental design as appropriate.

Outcome 3

Carry out a biological investigation.

Performance Criteria

(a) The experimental design is appropriate to the aim of the investigation.
(b) Ethical considerations in the use of living materials, human subjects and the conservation of natural habitats have been taken into account as appropriate.
(c) Potential hazards have been identified, associated risks assessed and appropriate control measures applied.
(d) Initial results are used to develop or confirm procedures in the experimental design.
(e) Consideration is given to collecting data with precision and accuracy.

National Unit specification: statement of standards (cont)

Unit title: Investigative Biology (SCQF level 7)

Evidence Requirements for this Unit

Evidence is required to demonstrate that candidates have achieved all Outcomes and Performance Criteria.

The standard to be applied and the breadth of coverage are illustrated in the National Assessment Bank items available for this Unit. If a centre wishes to design its own assessments for this Unit they should be of a comparable standard.

Written and/or oral evidence of an appropriate level of achievement must be generated from a closed-book instrument of assessment under controlled conditions covering all Performance Criteria for Outcome 1 and Outcome 2 with a time limit of 45 minutes. The instrument of assessment should take a holistic approach and comprise a test of structured short answer items. For Outcome 2 the test items should be based on material from scientific reports. All test items should be integrated into the instrument of assessment where appropriate and not sequenced according to Outcome.

The teacher/lecturer must confirm that the candidate has met all the Performance Criteria for Outcome 3 in carrying out a biological investigation. To gather this evidence the teacher/lecturer should employ a mixture of observing the candidate and having regular dialogue to discuss progress and to provide advice and support. This evidence must be recorded in a checklist.

In the evidence for Outcome 3 PC (a) the experimental design must include the aim of the investigation and formulate questions or hypotheses to be investigated. The experimental, observational and/or sampling procedures devised must include techniques and apparatus appropriate to the investigation and consider the need for controls and replicate treatments or samples.

National Unit specification: support notes

Unit title: Investigative Biology (SCQF level 7)

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

Outcome 1 and Outcome 2

1 Scientific principles and process
- (a) Scientific method
- (b) Scientific literature and communication
- (c) Scientific ethics

2 Experimentation
- (a) Pilot study
- (b) Variables
- (c) Experimental design
- (d) Controls
- (e) Sampling
- (f) Ensuring reliability

3 Critical evaluation of biological research
- (a) Evaluating background information
- (b) Evaluating experimental design
- (c) Evaluating data analysis
- (d) Evaluating conclusions

Further detail is given in the content tables in the Course specification.

Outcome 3

The topic chosen for investigation must be of a standard commensurate with the demands of Advanced Higher Biology. Any topic can be chosen provided it enables the Performance Criteria of the Unit to be achieved and can provide the basis for a report of the investigation for Course assessment if required. Both laboratory and fieldwork topics are suitable for investigation. Simulations or data handling exercises on their own are not suitable. Preliminary work such as developing techniques or apparatus and devising observational, experimental or sampling procedures are all suitable as part of the investigation. Topics for investigation should allow for the opportunity to modify procedures or to develop further investigative work based on experimental results. Investigation topics should have sufficient variables to investigate and where possible lead to results (whether qualitative or quantitative) that allow appropriate analysis.

National Unit specification: support notes

Unit title: Investigative Biology (SCQF level 7)

Guidance on learning and teaching approaches for this Unit

Outcome 1 and Outcome 2

The delivery of content and contexts for Outcome 1 and Outcome 2 could be approached in a number of ways. They could be delivered early in the Course prior to candidates embarking on their investigation or they could be delivered in conjunction with the investigation as the candidate progresses. Alternatively suitable learning approaches and practical work could be integrated into the other two Units of the Course as appropriate to overcome Outcome 1 and Outcome 2.

Outcome 3

The teacher/lecturer should encourage creativity and originality in the choice of topic for investigation by the candidate. The investigation is not required to be original research but should be new to the candidate. The topic for investigation should be generated by the candidate and be of interest and relevance to them. The topic need not be drawn from the biology in the Advanced Higher Course; topics previously encountered by the candidate or from outwith their direct learning experience can be suitable. The teacher/lecturer should support the candidate by advising on realistic and suitable procedures that will be achievable within the given time scale. This may involve consideration of laboratory facilities and equipment, seasonal considerations for fieldwork and the necessary control measures required as a result of risk assessment.

Candidates should be supported in identifying suitable topics for investigation and in devising experimental designs but should not be given excessive direction or support. Rather the candidate should be encouraged and directed to reflect on the learning in this Unit and supported to apply that learning to their investigation through open ended discussion with their teacher/lecturer. The teacher/lecturer should maintain regular scheduled dialogue with the candidate throughout their investigation to assess their progress and to give advice, support and encouragement. Excessive direction to candidates can be avoided by referring the candidate to the *Advanced Higher Biology (revised) Candidate Investigation Guidance* and to the learning acquired in the Unit and by directing the candidate to reflect on these. Through discussion and dialogue with the candidate and by observation and supervision of their practical work the teacher/lecturer will be able to gather evidence to assess the candidate's success in achieving the Performance Criteria for Outcome 3.

Candidates should be encouraged to maintain a laboratory record in which they note preliminary thoughts, plans and designs at the start of their investigation as well as their methods and results as these notes will form the basis of the investigation report for Course assessment. They should maintain a brief record of their discussions and dialogue with their teacher/lecturer. Preliminary pilot studies and early thoughts and ideas should also be recorded as credit can be gained by referring to these and including them in the investigation report for Course assessment even if they were not pursued in the main body of the investigation. Initial reading and research by the candidate, although important, should not absorb too much time and delay preliminary practical work. Suitable sources for initial reading include school and undergraduate textbooks, newspaper and media items, medical and government reports, scientific journals such as *School Science Review*, *New Scientist* and *Scientific American* and internet websites.

National Unit specification: support notes (cont)

Unit title: Investigative Biology (SCQF level 7)

The laboratory record could include:

- A record of discussion with teachers/lecturers and other scientists as appropriate
- background research
- references
- details of procedures
- results recorded
- analysis and presentation of results in appropriate forms, eg tables, graphs
- statement of findings/conclusions
- modifications and suggestions for further research.

Opportunities for Core Skill development

In this Unit candidates will develop skills that are valuable for personal development, for future learning and employability. Candidates will develop analytical and evaluative skills in reading and understanding reports of biological research and in evaluating biological data. In carrying out a biological investigation candidates will design an investigation and plan and organise experimental work. These are good opportunities for developing Core Skills, including:

- Written Communication
- *Numeracy*
- *Problem Solving*.

Guidance on approaches to assessment for this Unit

The instrument of assessment for Outcome 1 and Outcome 2 should be holistic and consist of test items that allow candidates to demonstrate their knowledge of biological research and experimental design. The instrument of assessment should contain a report of scientific research that can be critically evaluated by the candidate. It should contain information in the form of text as well as data that the candidate can relate to their existing knowledge, use to provide explanations or express an opinion on. Suitable experimental designs in the report of scientific research could include, fieldwork, surveys, field trials, clinical trials, experiments with controls, multifactorial experiments or experiments repeated with different independent variables. Raw data included should allow for the computation of means, percentages or ratios as appropriate. Opportunities to arrange raw data appropriately in columns and rows in a suitable table and the conversion of large numerical values to scientific notation are also suitable ways of processing data. Results should allow for evaluation by measures of central tendency, range and by statistical information such as standard error or least significant differences. Results should include variables that require the candidate to make decisions on the most appropriate way to represent them graphically. Conclusions drawn in the scientific report should be critically evaluated against existing knowledge, the aim of the study, the experimental design and the results as appropriate.

National Unit specification: support notes (cont)

Unit title: Investigative Biology (SCQF level 7)

For Outcome 3 the check list for evidence should record the ability of candidates to meet the Performance Criteria by having an appropriate experimental design, using initial results to confirm or develop procedures, dealing with ethical and safety issues and giving consideration to the way experimental data is collected. A suitable checklist with suggestions to aid professional judgement is shown below.

Unit title: Investigative Biology (SCQF level 7)

Checkpoint	Suggestions to aid professional judgement	Check (√)
Stated the aim of the investigation and formulated questions or hypotheses to be investigated.	The candidate has developed ideas for an investigation by reviewing and discussing previous learning and/or researching appropriate sources of information. The purpose of the investigation is clear and/or questions to be investigated and/or hypotheses to be tested have been formulated.	
Devised appropriate experimental, observational and sampling procedures, techniques and apparatus.	The procedures devised are appropriate to the aim of the investigation. The candidate has selected an appropriate procedure after considering or trying alternatives or becoming proficient in the procedure.	
Considered the need for controls and replicate treatments or samples.	Use of negative and positive controls and the control of potential confounding variables has been considered as appropriate. The need for repeated measurements, replicate treatments or samples and repeated experiments has been considered.	
Taken into account the ethical use of living materials, human subjects and the conservation of natural habitats.	The candidate has developed knowledge of and taken into account any ethical issues relevant to the investigation.	
Identified potential hazards, assessed their associated risks and applied appropriate control measures.	The candidate is aware of any potential hazards and has used the appropriate control measures to control risks in carrying out the investigation.	
Initial results have been used to devise further experiments or to confirm the appropriateness of a procedure for further work.	Experimental findings have been reviewed and further steps identified and carried out if appropriate.	
Made observations and recorded measurements with appropriate precision and accuracy.	Observations and/or measurements are recorded in a planned and organised way. Consideration has been given to the precision and accuracy of results.	

National Unit specification: support notes (cont)

Unit title: Investigative Biology (SCQF level 7)

Opportunities for the use of e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or e-checklists. Centres which wish to use e-assessment must ensure that the national standard is applied to all candidate evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. Further advice is available in *SQA Guidelines on Online Assessment for Further Education (AA1641, March 2003), SQA Guidelines on e-assessment for Schools (BD2625, June 2005)*.

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