Advanced Higher Course Assessment Specification

Advanced Higher Biology Course Assessment Specification (C707 77)

Valid from August 2015

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Please refer to the note of changes at the end of this Course Assessment Specification for details of changes from previous version (where applicable).

Course outline

Course title:	Advanced Higher Biology
SCQF level:	7 (32 SCQF credit points)
Course code:	C707 77
Course assessment code:	X707 77

The purpose of the Course Assessment Specification is to ensure consistent and transparent assessment year on year. It describes the structure of the Course assessment and the mandatory skills, knowledge and understanding that will be assessed.

Course assessment structure

Component 1 — question paper	90 marks
Component 2 — project	30 marks
Total marks	**120 marks**

This Course includes eight SCQF credit points to allow additional time for preparation for Course assessment. The Course assessment covers the added value of the Course.

Equality and inclusion

This Course Assessment Specification has been designed to ensure that there are no unnecessary barriers to assessment. Assessments have been designed to promote equal opportunities while maintaining the integrity of the qualification.

For guidance on assessment arrangements for disabled learners and/or those with additional support needs, please follow the link to the Assessment Arrangements web page: www.sqa.org.uk/sqa/14977.html.

Guidance on inclusive approaches to delivery and assessment of this Course is provided in the *Course Support Notes*.

Assessment

To gain the award of the Course, the learner must pass all the Units as well as the Course assessment. Course assessment will provide the basis for grading attainment in the Course award.

Course assessment

SQA will produce and give instructions for the production and conduct of Course assessments based on the information provided in this document.

Added value

The purpose of the Course assessment is to assess added value of the Course as well as confirming attainment in the Course and providing a grade. The added value for the Course will address the key purposes and aims of the Course, as defined in the Course Rationale. It will do this by addressing one or more of breadth, challenge, or application.

In this Course assessment, added value will focus on the following:

- breadth — drawing on knowledge and skills from across the Course
- challenge — requiring greater depth or extension of knowledge and/or skills
- application — requiring application of knowledge and/or skills in practical or theoretical contexts, as appropriate

This added value consists of:

- a question paper, which requires learners to demonstrate aspects of challenge and application; learners will apply breadth and depth of skills, knowledge and understanding from across the Course to answer questions in biology
- a project which requires learners to demonstrate aspects of challenge and application; learners will apply skills of scientific inquiry, using related knowledge, to carry out a meaningful and appropriately challenging task in biology and communicate findings

Grading

Course assessment will provide the basis for grading attainment in the Course award.

The Course assessment is graded A–D. The grade is determined on the basis of the total mark for all Course assessments together.

A learner's overall grade will be determined by their performance across the Course assessment.

Grade description for C
For the award of Grade C, learners will have demonstrated successful performance in all of the Units of the Course. In the Course assessment, learners will typically have demonstrated successful performance in relation to the mandatory skills, knowledge and understanding for the Course, by:

- retaining knowledge and scientific skills over an extended period of time
- integrating knowledge and understanding, and scientific skills, acquired through the study of the component Units
- applying knowledge and understanding and scientific skills set in contexts similar to those associated with the component Units
- applying knowledge and understanding, and scientific skills, to solve problems
- selecting, analysing and presenting relevant information collected through experimental, observational or research work
- reporting in a scientific manner which communicates the biology relating to the Course

Grade description for A
For the award of Grade A, learners will have demonstrated successful performance in all of the Units of the Course. In the Course assessment, learners will typically have demonstrated a high level of performance in relation to the mandatory skills, knowledge and understanding for the Course.

In addition, learners achieving a Grade A will have demonstrated a high overall level of performance by:

- retaining an extensive range of knowledge and scientific skills over an extended period of time
- integrating an extensive range of knowledge and understanding and scientific skills acquired across the component Units
- applying knowledge and understanding and scientific skills in less familiar and/or more complex contexts than in the component Units
- integrating knowledge and understanding and scientific skills to solve problems in less familiar and/or more complex contexts
- showing proficiency in selecting, analysing and presenting relevant information collected through experimental, observational or research work
- showing proficiency in reporting in a scientific manner that communicates the biology relating to the Course by analysing and interpreting information in a critical and scientific manner and demonstrating depth of knowledge and understanding

Credit
To take account of the extended range of learning and teaching approaches, remediation, consolidation of learning and integration needed for preparation for external assessment, six SCQF credit points are available in Courses at National 5 and Higher, and eight SCQF credit points in Courses at Advanced Higher. These points will be awarded when a Grade D or better is achieved.

Structure and coverage of the Course assessment

The Course assessment will consist of two Components: a question paper and a project.

Component 1 — question paper
The purpose of this question paper is to assess breadth and depth of knowledge and understanding from across the Units.

The question paper will assess scientific inquiry skills and analytical thinking skills. The question paper will give learners an opportunity to demonstrate the following skills, knowledge and understanding by:

- demonstrating knowledge and understanding of biology by making statements, describing information, providing explanations and integrating knowledge
- applying knowledge of biology to new situations, interpreting information and solving problems
- planning or designing experiments/investigations, including safety measures, to test given hypotheses or to illustrate particular effects
- selecting information from a variety of sources and presenting information, appropriately, in a variety of forms
- processing information/data (using calculations and units, where appropriate)
- making predictions and generalisations based on evidence/information
- drawing valid conclusions and giving explanations supported by evidence/justification
- identifying a source of error and suggesting improvements to experiments

The mandatory skills and knowledge are specified in the 'Further mandatory information on Course coverage' section at the end of this Course Assessment Specification.

The question paper will have 90 marks.
The question paper will have two Sections.

Section 1 will contain objective questions and will have 25 marks.

Section 2 will contain restricted and extended response questions and will have 65 marks.

Marks will be distributed approximately proportionately across the Units.

The majority of the marks will be awarded for applying knowledge and understanding. The other marks will be awarded for applying scientific inquiry and problem solving skills.

For more information about the structure and coverage of the Question Paper, refer to the Question Paper Brief.

Component 2 — project
The purpose of the project is to allow the learner to carry out an in-depth investigation of a biology topic and produce a project–report. Prior to starting this assessment, learners should have started a biology investigation as part of the *Investigative Biology* Unit. In this Unit, learners are required to plan and carry out

a biology investigation. Learners should keep a record of their work as this may form the basis of their project–report. This record should include details of their research, experiments and recorded data. The topic will be chosen by the learner, who will individually investigate/research the underlying biology.
This is an open-ended task which may involve a significant part of the work being carried out without close supervision. The learner will extend and apply the skills of independent/autonomous working. This includes making independent and rational decisions based on evidence and interpretation of scientific information, and the analysis and evaluation of their results. This will further develop and enhance their scientific literacy.

The project will assess the application of skills of scientific inquiry and related biology knowledge and understanding. The project will give learners an opportunity to demonstrate the following skills, knowledge and understanding by:

- extending and applying knowledge of biology to new situations, interpreting and analysing information to solve complex problems
- planning and designing biological experiments/investigations, using reference materials and including risk assessments, to test a hypothesis or to illustrate particular effects
- recording systematic detailed observations and collecting data
- selecting information from a variety of sources and presenting detailed information, appropriately, in a variety of forms
- processing and analysing biological information (using calculations, significant figures and units, where appropriate)
- making reasoned predictions and generalisations from a range of evidence/information
- drawing valid conclusions and giving explanations supported by evidence/justification
- critically evaluating experimental procedures by identifying sources of error, suggesting and implementing improvements
- drawing on knowledge and understanding of biology to make accurate statements, describe complex information, provide detailed explanations and integrate knowledge
- communicating biological findings/information fully and effectively
- analysing and evaluating scientific publications and media reports

The project will have 30 marks.

The majority of the marks will be awarded for applying scientific inquiry skills. The other marks will be awarded for applying related knowledge and understanding.

The learner will submit their project–report as evidence. The project–report will be externally assessed using the following assessment categories:

Category	Mark allocation
Abstract	1
Introduction	5
Procedures	9
Results	6
Discussion (conclusion(s) and evaluation)	7
Presentation	2
Total	30

Setting, conducting and marking of assessment

Question paper

This question paper will be set and marked by SQA, and conducted in centres under conditions specified for external examinations by SQA. Learners will complete this in 2 hours and 30 minutes.

Controlled assessment — project

This project is:

- set by centres within SQA guidelines
- conducted under some supervision and control

and

- evidence will be submitted to SQA for external marking.

All marking will be quality assured by SQA.

The production of evidence for the project will be conducted:

- in time to meet a submission date set by SQA
- independently by the learner

Further mandatory information on Course coverage

The following gives details of mandatory skills, knowledge and understanding for the Advanced Higher Biology Course. Course assessment will involve sampling the skills, knowledge and understanding. This list of skills, knowledge and understanding also provides the basis for the assessment of Units of the Course.

The following gives details of the skills:

- extending and applying knowledge of biology to new situations, interpreting and analysing information to solve complex problems
- planning and designing biological experiments/investigations, using reference materials and including risk assessments, to test a hypothesis or to illustrate particular effects
- carrying out complex experiments in biology safely, recording systematic detailed observations and collecting data
- selecting information from a variety of sources and presenting detailed information appropriately in a variety of forms
- processing and analysing biological information (using calculations, significant figures and units, where appropriate)
- making reasoned predictions and generalisations from a range of evidence/information
- drawing valid conclusions and giving explanations supported by evidence/justification
- critically evaluating experimental procedures by identifying sources of error, suggesting and implementing improvements
- drawing on knowledge and understanding of biology to make accurate statements, describe complex information, provide detailed explanations and integrate knowledge
- communicating biological findings/information fully and effectively
- analysing and evaluating scientific publications and media reports

These skills will be assessed, across the Course, in the context of the mandatory knowledge.

The following table provides further detail of the mandatory knowledge for the Advanced Higher Biology Course.

Biology: Cells and Proteins

1 Laboratory techniques for biologists (a) Health and safety
(b) Liquids and solutions The use of: linear and log dilution series; standard curve for determination of an unknown; buffers to control pH; colorimeter to quantify concentration.
(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. Size and charge are factors affecting protein migration in a gel. Proteins can be separated using pH; at their iso-electric point they have an overall neutral charge and precipitate out of solution.
(d) Antibody techniques 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 labelled antibodies in protein blotting and immunohistochemical staining of tissue. Monoclonal antibodies are produced using hybridomas formed from the fusion of a B lymphocyte with a myeloma cell using polyethylene glycol (PEG).
(e) Microscopy Use of bright field to examine whole organisms, parts of organisms or thin sections of dissected tissue. Fluorescence microscopy allows particular protein structures to be visualised.
(f) Aseptic technique and cell culture Use of inoculum, explants or cells. Use of: haemocytometers to estimate total cell counts; vital staining to estimate viable 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.
2 Proteins (a) Proteomics The proteome is the entire set of proteins expressed by a genome. The proteome is larger than the number of genes due to alternative RNA splicing and post-translational modification. Not all genes are expressed as proteins in a particular cell.
(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 structure is the sequence 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. Structure of amino acids including main classes of R groups based on functional group: basic (positively charged); acidic (negatively charged); polar; hydrophobic. The polypeptide folds into a tertiary structure; this conformation is caused by bonding, such as interactions of the R groups in hydrophobic regions, ionic bonds, van der Waals interactions (including hydrogen bonds) and disulfide bridges. Prosthetic group is a non-protein unit tightly bound to a protein necessary for its function. Quaternary structure exists in proteins with several connected polypeptide subunits. Interactions of the R groups can be influenced by temperature and pH.
(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.

(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) Ligand 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. Induced fit in enzymes occurs when the correct substrate starts to bind resulting in a temporary change in shape of the active site increasing the binding and interaction with the substrate.
Activation energy; binding of modulators at secondary binding sites in allosteric enzymes; positive and negative modulators. The conformation of the enzyme changes and this alters the affinity of the active site 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.

(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.

3 Membrane proteins
(a) 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 specialised 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.

(b) 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.

(c) 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.

(d) 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 at a synapse. 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.

4 Detecting and amplifying an environmental stimulus

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 to form the photoreceptors of the eye. A cascade of proteins amplifies the signal.

In rod cells the retinal-opsin complex is called rhodopsin. 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. A very high degree of amplification results in sensitivities at low light intensities. In cone cells, different forms of opsin combine with retinal to give photoreceptor proteins, each with maximal sensitivity to specific wavelengths (red, green, blue or UV).

5 Communication within multicellular organisms

(a) Coordination

Receptor molecules of target cells are proteins with a binding site for a specific 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.

(b) Hydrophobic signals and control of transcription

Hydrophobic signalling molecules can diffuse through membranes so their receptor molecules can be within the nucleus.

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 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.

(c) 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 on the cell surface; 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.

6 Protein control of cell division

(a) 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 organising centre). Microtubules form the spindle fibres, which are active during cell division.

(b) The cell cycle

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 G1 followed by an S phase where the cell continues to grow and copies its chromosomes and a further G2 growth phase, in preparation for M phase (mitosis and cytokinesis).
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 is the separation of the cytoplasm into daughter cells.

(c) Control of the cell cycle

Progression through the cell cycle is regulated by checkpoints at G1, G2 and metaphase. Checkpoints are critical control points where stop and go ahead signals regulate the cycle. If a go ahead signal is not reached at the G1 checkpoint the cell may switch to a non-dividing state called the G0 phase.
As the cell size increases during G1, cyclin proteins accumulate and combine with regulatory proteins called cyclin-dependent kinases (Cdks) and activate them. Active 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 G1 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.

(d) Control of apoptosis

Programmed cell death (apoptosis) is triggered by cell death signals that activate inactive forms of DNAase and proteinases (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.

Biology: Organisms and Evolution

1 Field techniques for biologists

(a) Health and safety

(b) Sampling of wild organisms

Sampling should be carried out in a manner that minimises 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 sessile and 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.

(c) Identification and taxonomy

Identification of a sample can be made using classification guides, biological keys or analysis of DNA or protein. 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.

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). Model organisms from within all taxonomic groups are used to obtain information that can be applied to species that are more difficult to study directly. Model organism that have been very important in the advancement of modern biology include the bacterium *E. coli*; the flowering plant *Arabidopsis thaliana;* the nematode *C. elegans*; the arthropod *Drosophila melanogaster* and mice, rats and zebrafish which are chordates.

(d) Monitoring populations

Presence, absence or abundance of indicator species can give information of environmental qualities, such as presence of pollutant.

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 minimise the impact on the study species.

(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.

2 Evolution

(a) 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.
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.

(b) 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.

(c) Co-evolution and the Red Queen Hypothesis
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 ongoing co-evolution between a parasite and host, as exemplified in the Red Queen hypothesis. Hosts better able to resist and tolerate parasitism have greater fitness. Parasites better able to feed, reproduce and find new hosts have greater fitness.

3 Variation and sexual reproduction

(a) Costs and benefits of sexual and asexual reproduction
Comparison of the costs and benefits of sexual and asexual reproduction
Disadvantages of sexual reproduction: males unable to produce offspring; only half of each parent's genome passed onto offspring disrupting successful parental genomes. Benefits outweigh disadvantages due to increase in genetic variation in the population. This genetic variation provides the raw material required to continue adapting 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 that are disadvantageous to parasites or regions of low parasite density/diversity. Organisms that reproduce principally by asexual reproduction often have mechanisms for horizontal gene transfer between individuals, such as the plasmids of bacteria and yeast.

(b) Meiosis forms variable gametes
Homologous chromosomes are pairs of chromosomes of the same size, same centromere position and with the same genes at the same loci.
Mechanism by which variation is increased through the production of haploid gametes by meiosis in gamete mother cells. Meiosis I including: pairing of homologous chromosomes; random crossing over at chiasmata resulting in exchange of DNA between homologous pairs and recombination of alleles of linked genes; independent assortment and separation of parental chromosomes irrespective of their maternal and paternal origin. Meiosis II including: including separation of sister chromatids/chromosomes; gamete formation. 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.

(c) Sex determination
Many species are hermaphroditic. For some species environmental rather than genetic factors determine sex and sex ratio. Sex can change within individuals of

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 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 (XBXb) and affected males (XbY). 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, which could be harmful to cells. Carriers are less likely to be affected 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.

4 Sex and behaviour

(a) Parental 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. Classification of r-selected and K-selected organisms.
Various reproductive strategies have evolved ranging from polygamy to monogamy.

(b) 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.
Females generally inconspicuous; males have more conspicuous markings, structures and behaviours.
Female choice: involves females assessing honest signals of 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. Reversed sexual dimorphism in some species. Successful courtship behaviour in birds and fish can be a result of species-specific sign stimuli and fixed action pattern responses. Imprinting: irreversible developmental processes that occur during a critical time period in young birds may influence mate choice later in life.

5 Parasitism

(a) The parasite niche

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 are very host specific. As the host provides so many of the parasite's needs, many parasites are degenerate, lacking in structures and organs found in other organisms.
An ectoparasite lives 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. 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.

(b) Transmission and virulence

Transmission is the spread of a parasite to a host. Virulence is the harm caused to a

host species by a parasite. Factors that increase transmission rates: the overcrowding of hosts at high density; mechanisms that allow the parasite to spread even when infected hosts are incapacitated, such as vectors and waterborne dispersal stages. 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.

(c) 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 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 faster than the host immune system can respond to the new antigens.

(d) Parasitic life cycles
Common parasites include protists, platyhelminths, nematodes, arthropods, bacteria and viruses. Many parasites require more than one host to complete their life cycle, eg *Plasmodium spp*. which causes the human disease malaria and the platyhelminth, *Schistosoma spp.,* which causes schistosomiasis in humans. Ectoparasites and endoparasites of the main body cavities, such as the gut, are generally transmitted through direct contact or by consumption of secondary hosts. Endoparasites of the body tissues are often transmitted by vectors. Other parasites can complete their life cycle within one host, eg some endoparasitic amoebas and ectoparasitic arthropods, bacteria and viruses. Human diseases include tuberculosis, caused by bacteria, and influenza and HIV caused by viruses.
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. 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.

(e) Challenges in treatment and control
Some 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.
Challenges arise where parasites spread most rapidly as a result of overcrowding or tropical climates. 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.

Investigative Biology

1 Scientific principles and process

(a) Scientific method

Scientific cycle — construction of a testable hypothesis, experimental design, gathering, recording, analysis of data, evaluation of results, conclusions and the formation of new hypotheses where necessary. The null hypothesis.

(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.

The importance of peer review and critical evaluation. The use of review articles, which summarise current knowledge and recent findings in a particular field. Critical evaluation of science coverage in the wider media.

(c) Scientific ethics

Importance of integrity and honesty — unbiased presentation of results, citing and providing references, avoiding plagiarism.

In animal studies, the concepts of replacement, reduction and refinement are used to avoid, reduce or minimise the harm to animals. Informed consent, the right to withdraw data and confidentiality in human studies. The justification for scientific research including the assessment of any risks.

Legislation, regulation, policy and funding can all influence scientific research.

2 Experimentation

(a) Pilot study

The use of a pilot study to develop and/or practice protocols in order to ensure validity of experimental design, check effectiveness of techniques, find a suitable range of values for the independent variable, identify and control confounding variables, identifying suitable numbers of replicates.

(b) Variables

Controlling and or monitoring confounding variables, including randomised block design.

Discrete and continuous variables give rise to qualitative, quantitative or ranked data.

(c) Experimental design

Controls, dependent and independent variables. The use and limitations of simple (one independent variable) and multifactorial (more than one independent variable) experimental designs.

Advantages and disadvantages in vivo and in vitro studies.

Investigators 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.

(d) Controls

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.

(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.

(f) Ensuring reliability Variation in experimental results may be due to the reliability of measurement methods and/or inherent variation in the specimens. The precision and accuracy of repeated measurements. 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. Repeating experiments as a whole to check the reliability of results.
3 Critical evaluation of biological research (a) Evaluating background information. Scientific reports should contain – an explanatory title, a summary including aims and findings, an introduction explaining the purpose and context of study including the use of several sources, supporting statements, citations, and references. A method section should contain sufficient information to allow another investigator to repeat the work.
(b) Evaluating experimental design Experimental design should test the intended aim or hypothesis. Treatment effects should be compared to controls and any confounding variables. The effect of selection bias and sample size on representative sampling.
(c) Evaluating data analysis The appropriate use of graphs, mean, median, mode, standard deviation and range in interpreting data. 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. 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.
(d) Evaluating conclusions Conclusions should refer to the aim, the results and the hypothesis. The validity and reliability of the experimental design should be taken into account. Consideration should be given as to whether the results can be attributed to correlation or causation. Conclusions should also refer to existing knowledge and the results of other investigations.

Administrative information

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History of changes to Course Assessment Specification

Course details	Version	Description of change	Authorised by	Date
	2.0	Significant change to Course assessment structure. Significant changes to structure and coverage of the Course assessment. Significant changes to clarify mandatory knowledge.	Qualifications Development Manager	April 2015
	2.1	Minor typographical change made: 'Evolution' heading replaces 'Organisms' in 'Biology: Organisms and Evolution' section.	Qualifications Manager	September 2015
	2.2	Reference to Question Paper Brief inserted.	Qualifications Manager	April 2016