Course/Unit Support Notes

Advanced Higher Biology
Draft Course/Unit Support Notes

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

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Contents

Introduction

These support notes are not mandatory. They provide advice and guidance on approaches to delivering and assessing the Advanced Higher Biology Course. They are intended for teachers and lecturers who are delivering the Course and its Units. They should be read in conjunction with the *Course Specification*, the *Course Assessment Specification* and the *Unit Specifications* for the Units in the Course.

These support notes cover both the Advanced Higher Course and the Units in it.

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General guidance on the Course/Units

Aims

The aims of the Course are to enable learners to:

- develop a critical understanding of the role of biology in scientific issues and relevant applications, including the impact these could make on the environment/society.
- extend and apply knowledge, understanding and skills of biology
- develop and apply the skills to carry out complex practical scientific activities, including the use of risk assessments, technology, equipment and materials
- develop and apply inquiry and investigative skills, including planning and experimental design
- develop and apply scientific analytical thinking skills, including critical evaluation of experimental procedures
- extend and apply problem solving skills in a biology context
- further develop an understanding of scientific literacy, using a wide range of resources, in order to communicate complex ideas and issues and to make scientifically informed choices
- extend and apply skills of independent/autonomous working in biology

Progression

In order to do this Course, learners should have achieved the Higher Biology or Human Biology Course.

Learners who have achieved this Advanced Higher Course may progress to further study, employment and/or training. Opportunities for progression include:

- Progression to further/higher education
  - For many learners a key transition point will be to further or higher education, for example to Professional Development Awards (PDAs), Higher National Certificates (HNCs) or Higher National Diplomas (HNDs) or degree programmes. Examples of further and higher education programmes that learners doing the Course might progress to include medicine, dentistry, veterinary medicine, professions allied to medicine, horticulture, pharmacology, environmental science and health.

  - Advanced Higher Courses provide good preparation for learners progressing to further and higher education as learners doing Advanced Higher Courses must be able to work with more independence and less supervision. This eases their transition to allow 'advanced standing' or partial credit towards the first year of study of a degree programme.

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— Advanced Higher Courses are challenging and testing qualifications — learners who have achieved multiple Advanced Higher Courses are regarded as having a proven level of ability which attests to their readiness for education in higher education institutions (HEIs) in other parts of the UK as well as in Scotland.

- Progression to employment
  — For many learners progression will be directly to employment or work-based training programmes. Examples of employment opportunities and training programmes are careers in the health sector, agricultural science, education, environmental services.

This Advanced Higher is part of the Scottish Baccalaureate in Science. The Scottish Baccalaureates in Expressive Arts, Languages, Science and Social Sciences consist of coherent groups of subjects at Higher and Advanced Higher level. Each award consists of two Advanced Highers, one Higher and an Interdisciplinary Project which adds breadth and value and helps learners to develop generic skills, attitudes and confidence that will help them make the transition into higher education or employment.

Hierarchies

Hierarchy is the term used to describe Courses and Units which form a structured progression involving two or more SCQF levels.

It is important that any content in a Course and/or Unit at one particular SCQF level is not repeated if a learner progresses to the next level of the hierarchy. The skills and knowledge should be able to be applied to new content and contexts to enrich the learning experience. This is for centres to manage.

- Biology Courses from National 3 to Advanced Higher are hierarchical.
- Courses from National 3 to National 5 have Units with the same structure and titles.

Higher Biology and Higher Human Biology give equal progression to Advanced Higher Biology.

Skills, knowledge and understanding covered in this Course

Teachers and lecturers should refer to the *Course Assessment Specification* for mandatory information about the skills, knowledge and understanding to be covered in this Course.

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Approaches to learning and teaching

The purpose of this section is to provide you with advice on learning and teaching. It is essential that you are familiar with the mandatory information within the Advanced Higher Biology *Course Assessment Specification*.

Advanced Higher Courses place more demands on learners as there will be a higher proportion of independent study and less direct supervision. Some of the approaches to learning and teaching suggested for other levels (in particular, Higher) may also apply at Advanced Higher level but there will be a stronger emphasis on independent learning.

As with the Higher Biology and Higher Human Biology Courses, learning at Advanced Higher level is still expected to be experiential, active, challenging and enjoyable. It should include appropriate practical experiments/activities and could be learner led. The use of a variety of active learning approaches is encouraged, including peer teaching and assessment, individual and group presentations, and game-based learning with learner-generated questions.

For Advanced Higher Courses, a significant amount of learning may be self-directed and require learners to demonstrate a more mature approach to learning and the ability to work on their own initiative. This can be very challenging for some learners, who may feel isolated at times, and teachers and lecturers should have strategies for addressing this. These could include, for example, planning time for regular feedback sessions/discussions on a one-to-one basis and on a group basis led by the teacher or lecturer (where appropriate).

Centres should be aware that although the mandatory knowledge and skillset may be similar in Higher and Advanced Higher Courses, there may be differences in the:

- depth of underpinning knowledge and understanding
- complexity and sophistication of the applied skills
- ways in which learners will learn: namely, they will take more responsibility for their learning at Advanced Higher and work more autonomously

All learning and teaching should offer opportunities for learners to work collaboratively. Practical activities and investigative work can offer opportunities for group work, which should be encouraged. Laboratory work should include the use of technology and equipment that reflects current scientific use in biology. Fieldwork provides an opportunity for practical work, using first-hand experience of an ecosystem to develop knowledge, understanding and problem solving. Appropriate risk assessment must be undertaken.

Learners, especially at Advanced Higher, would be expected to contribute a significant portion of their own time in addition to programmed learning time.

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Effective partnership working can enhance the science experience. Where feasible, locally relevant contexts should be studied, with visits where this is possible. Guest speakers from eg industry, further and higher education could be used to bring the world of biology into the classroom.

An investigatory approach is encouraged in Biology, with learners actively involved in developing their skills, knowledge and understanding by investigating a range of relevant biological applications and issues. A holistic approach should be adopted to encourage simultaneous development of learners' conceptual understanding and skills. Where appropriate, investigative work/experiments, in Biology, should allow learners the opportunity to select activities and/or carry out extended study. Investigative and experimental work is part of the scientific method of working and can fulfil a number of educational purposes.

Teachers and lecturers should encourage learners to use an enquiring, critical and problem-solving approach to their learning. Learners should also be given the opportunity to practise and develop research and investigation skills and higher order evaluation and analytical skills.

The use of information and communications technology (ICT) can make a significant contribution to the development of these higher order skills as research and investigation activities become more sophisticated. ICT can make a significant contribution to practical work in Advanced Higher 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 long or short periods of 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 that can then be downloaded and viewed for analysis.

Skills of scientific experimentation, investigation and inquiry

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.

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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 biology-related 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

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- 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 the Royal Society of Chemistry 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

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- 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 of other learners 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:

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- 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 information
- use modelling and simulation software to test predictions and answer questions related to physical and experimental phenomena
- use evidence to support a personal decision or point of view on a current scientific or technological issue

Learners will engage in a variety of learning activities as appropriate to the subject, details of approaches and contexts are suggested in Appendix 1.

Teachers and lecturers should support learners by having regular discussions with them and giving regular feedback. Some learning and teaching activities may be carried out on a group basis and, where this applies, learners could also receive feedback from their peers.

Teachers and lecturers should, where possible, provide opportunities to personalise learning for learners, and to enable them to have choices in approaches to learning and teaching. The flexibility in Advanced Higher Courses and the independence with which learners carry out the work lend themselves to this. Teachers and lecturers should also create opportunities for, and use, inclusive approaches to learning and teaching. This can be achieved by encouraging the use of a variety of learning and teaching strategies which suit the needs of all learners. Innovative and creative ways of using technology can also be valuable in creating inclusive learning and teaching approaches.

Centres are free to sequence the teaching of the Course, Units, key areas and Outcomes in any order they wish.

- Each Unit could be delivered separately in any sequence.
  And/or
- All Units may be delivered in a combined way as part of the Course. If this approach is used, the Outcomes within Units may either be partially or fully combined.

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Learning about Scotland and Scottish culture will enrich the learners' learning experience and help them to develop the skills for learning, life and work they will need to prepare them for taking their place in a diverse, inclusive and participative Scotland and beyond. Where there may be opportunities to contextualise approaches to learning and teaching to Scottish contexts in this Course, this could be done through mini-projects or case studies.

Developing skills for learning, skills for life and skills for work

It is important that learners are aware of the skills for learning, skills for life and skills for work that they are developing in the Course and the activities they are involved in that provide realistic opportunities to practise and/or improve these skills. Teachers and lecturers should ensure that learners have opportunities to develop these skills as an integral part of their learning experience.

At Advanced Higher level it is expected that learners will be using a range of higher order thinking skills. They will also develop skills in independent and autonomous learning.

Learners are expected to develop broad generic skills as an integral part of their learning experience. The *Course Specification* lists the skills for learning, skills for life and skills for work that learners should develop through this Course. These are based on SQA's *Skills Framework: Skills for Learning, Skills for Life and Skills for Work* and must be built into the Course where there are appropriate opportunities. The level of these skills will be appropriate to the level of the Course.

For this Course, it is expected that the following skills for learning, skills for life and skills for work will be significantly developed:

Literacy
Writing means the ability to create texts which communicate ideas, opinions and information, to meet a purpose and within a context. In this context, 'texts' are defined as word-based materials (sometimes with supporting images) which are written, printed, Braille or displayed on screen. These will be technically accurate for the purpose, audience and context.

1.1 Reading
Learners will understand and interpret a variety of scientific texts.

1.2 Writing
Learners use skills to effectively communicate key areas of biology, make informed decisions and explain, clearly, biological issues in various media forms. Learners will have the opportunity to communicate applied knowledge and understanding throughout the Course.

There will be opportunities to develop the literacy skills of listening and reading, when gathering and processing information in Biology.

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Numeracy
This is the ability to use numbers in order to solve problems by counting, doing calculations, measuring, and understanding graphs and charts. This is also the ability to understand the results.

Learners will have opportunities to extract, process and interpret information presented in numerous formats including tabular and graphical. Practical work will provide opportunities to develop time and measurement skills.

2.1 Number processes
Number processes mean solving problems through carrying out calculations, when dealing with data and results from experiments/investigations and everyday class work, making informed decisions based on the results of these calculations and understanding these results.

2.2 Money, time and measurement
The accuracy of measurements is important when handling data in a variety of biology contexts, including practical and investigative. Consideration should be given to uncertainties.

2.3 Information handling
Information handling means being able to gather and interpret biological data in tables, charts and other graphical displays to draw sensible conclusions throughout the Course. It involves interpreting the data and considering its reliability in making reasoned deductions and informed decisions. It also involves an awareness and understanding of the chance of events happening.

Thinking skills
This is the ability to develop the cognitive skills of remembering and identifying, understanding and applying.

The Course will allow learners to develop skills of applying, analysing and evaluating. Learners can analyse and evaluate practical work and data by reviewing the process, identifying issues and forming valid conclusions. They can demonstrate understanding and application of key areas and explain and interpret information and data.

5.3 Applying
Applying is the ability to use existing information to solve biological problems in different contexts, and to plan, organise and complete a task such as an investigation.

5.4 Analysing and evaluating
This covers the ability to identify and weigh-up the features of a situation or issue in biology and to draw valid conclusions. It includes reviewing and considering any potential solutions.

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5.5 Creating
This is the ability to design something innovative or to further develop an existing thing by adding new dimensions or approaches. Learners can demonstrate their creativity, in particular, when planning and designing biology experiments or investigations. Learners have the opportunity to be innovative in their approach. Learners also have opportunities to make, write, say or do something new.

In addition, learners will also have opportunities to develop working with others and citizenship.

Working with others
Learning activities provide many opportunities, in all areas of the Course, for learners to work with others. Practical activities and investigations, in particular, offer opportunities for group work, which is an important aspect of biology and should be encouraged.

Citizenship
Learners will develop citizenship skills, when considering the applications of biology on our lives, as well as the implications for the environment/society.

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Approaches to assessment

Assessment in Advanced Higher Courses will generally reflect the investigative nature of Courses at this level, together with high-level problem-solving and critical thinking skills and skills of analysis and synthesis.

This emphasis on higher order skills, together with the more independent learning approaches that learners will use, distinguishes the added value at Advanced Higher level from the added value at other levels.

There are different approaches to assessment, and teachers and lecturers should use their professional judgement, subject knowledge and experience, as well as understanding of their learners and their varying needs, to determine the most appropriate ones and, where necessary, to consider workable alternatives.

Assessments must be fit for purpose and should allow for consistent judgements to be made by all teachers and lecturers. They should also be conducted in a supervised manner to ensure that the evidence provided is valid and reliable.

Unit assessment

Units will be assessed on a pass/fail basis. All Units are internally assessed against the requirements shown in the *Unit Specification*. Each Unit can be assessed on an individual Outcome-by-Outcome basis or via the use of combined assessment for some or all Outcomes.

Assessments must ensure that the evidence generated demonstrates, at the least, the minimum level of competence for each Unit. Teachers and lecturers preparing assessment methods should be clear about what that evidence will look like.

Sources of evidence likely to be suitable for Advanced Higher Units could include:

- meaningful contributions to group work and/or discussions (making use of log books, blogs, question and answer sessions to confirm individual learners have met the required standards)
- presentation of information to other groups and/or recorded oral evidence
- exemplification of concepts using (for example) a diagram
- interpretation of numerical data
- practical demonstration with commentary/explanation/narrative
- investigations
- answers to multiple choice questions
- short written responses
- extended response essay-type questions

Evidence should include the use of appropriate subject-specific terminology as well as the use of real-life examples where appropriate.

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Flexibility in the method of assessment provides opportunities for learners to demonstrate attainment in a variety of ways and so reduce barriers to attainment.

The structure of an assessment used by a centre can take a variety of forms, for example:

- individual pieces of work could be collected in a folio as evidence for Outcomes and Assessment Standards
- assessment of each complete Outcome
- assessment that combines the Outcomes of one or more Units
- assessment that requires more than the minimum competence, which would allow learners to prepare for the Course assessment

Teachers and lecturers should note that learners' day-to-day work may produce evidence which satisfies assessment requirements of a Unit, or Units, either in full or partially. Such naturally-occurring evidence may be used as a contribution towards Unit assessment. However, such naturally-occurring evidence must still be recorded and evidence such as written reports, recording forms, PowerPoint slides, drawings/graphs, video footage or observational checklists provided.

Combining assessment across Units

A combined approach to assessment will enrich the assessment process for the learner, avoid duplication of tasks and allow more emphasis on learning and teaching. Evidence could be drawn from a range of activities for a combined assessment. Care must be taken to ensure that combined assessments provide appropriate evidence for all the Outcomes that they claim to assess.

Combining assessment will also give centres more time to manage the assessment process more efficiently. When combining assessments across Units, teachers/lecturers should use e-assessment wherever possible. Learners can easily update portfolios, electronic or written diaries and recording sheets.

For some Advanced Higher Courses, it may be that a strand of work which contributes to a Course assessment method is started when a Unit is being delivered and is completed in the Course assessment. In these cases, it is important that the evidence for the Unit assessment is clearly distinguishable from that required for the Course assessment.

Preparation for Course assessment

Each Course has additional time which may be used at the discretion of the teacher or lecturer to enable learners to prepare for Course assessment. This time may be used near the start of the Course and at various points throughout the Course for consolidation and support. It may also be used for preparation for Unit assessment, and, towards the end of the Course, for further integration, revision and preparation and/or gathering evidence for Course assessment.

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For this Advanced Higher Course, the assessment methods for Course assessment are [question paper and project]. Learners should be given opportunities to practise these methods and prepare for them.

Examples of activities to include within this preparation time include:

- Preparing for the components of Course assessment, for example:
  - preparing for non-question paper components — selecting topics, gathering and researching information/data, evaluating and analysing findings, developing and justifying conclusions, presenting the information/data (as appropriate)
  - practising question paper techniques and revising for the question paper

In relation to preparing for the project, teachers and lecturers should explain requirements to learners and the amount and nature of the support they can expect. However, at Advanced Higher level it is expected that learners will work with more independence and less supervision and support.

Authenticity

In terms of authenticity, there are a number of techniques and strategies to ensure that learners present work that is their own. Teachers and lecturers should put in place mechanisms to authenticate learner evidence.

In Advanced Higher Courses, because learners will take greater responsibility for their own learning and work more independently, teachers and lecturers need to have measures in place to ensure that work produced is the learner's own work.

For example:

- regular checkpoint/progress meetings with learners
- short spot-check personal interviews
- checklists which record activity/progress
- photographs, films or audio records

Group work approaches are acceptable as part of the preparation for assessment and also for formal assessment, where appropriate. However, there must be clear evidence for each learner to show that the learner has met the Evidence Requirements.

For more information, please refer to SQA's *Guide to Assessment.*

Added Value

Advanced Higher Courses include assessment of added value which is assessed in the Course assessment.

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Information given in the *Course Specification* and the *Course Assessment Specification* about the assessment of added value is mandatory.

In Advanced Higher Courses, added value involves the assessment of higher order skills such as high-level and more sophisticated investigation and research skills, critical thinking skills and skills of analysis and synthesis. Learners may be required to analyse and reflect upon their assessment activity by commenting on it and/or drawing conclusions with commentary/justification. These skills contribute to the uniqueness of Advanced Higher Courses and to the overall higher level of performance expected at this level.

Units will be assessed on a pass/fail basis. All Units are internally assessed against the requirements shown in the *Unit Specification*. Each Unit can be assessed on an individual Outcome-by-Outcome basis or via the use of combined assessment for some or all Outcomes.

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

- 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

In this Course, added value will be assessed by means of the question paper and project.

In this Course, added value consists of a question paper and a project.

- The question paper is used to assess whether the learner can retain and consolidate the knowledge and skills gained in individual Units. It requires learners to demonstrate aspects of challenge and application. Learners will apply breadth and depth of skills, and the various applications of knowledge — such as reasoning, analysing, evaluating and solving problems from across the Course to answer questions in biology.

- The project is used to assess a wide range of high-order cognitive and practical skills and to bring them together, such as skills relating to planning, analysis, synthesis and evaluation. The project requires learners to apply skills of scientific inquiry, using related knowledge, to carry out a meaningful and appropriately challenging task in biology and communicate findings. The learner will carry out a significant part of the work for the project independently with minimal supervision.

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Equality and inclusion

It is recognised that centres have their own duties under equality and other legislation and policy initiatives. The guidance given in these *Course/Unit Support Notes* is designed to sit alongside these duties but is specific to the delivery and assessment of the Course.

It is important that centres are aware of and understand SQA's assessment arrangements for disabled learners, and those with additional support needs, when making requests for adjustments to published assessment arrangements. Centres will find more guidance on this in the series of publications on Assessment Arrangements on SQA's website: www.sqa.org.uk/sqa/14977.html.

The greater flexibility and choice in Advanced Higher Courses provide opportunities to meet a range of learners' needs and may remove the need for learners to have assessment arrangements. However, where a disabled learner needs a reasonable adjustment/assessment arrangements to be made, you should refer to the guidance given in the above link.

The following should be taken into consideration:

Situation	**Reasonable adjustment**
Carrying out practical activities	Use could be made of practical helpers for learners with: ♦ physical disabilities, especially manual dexterity, when carrying out practical activities ♦ visual impairment who have difficulty distinguishing colour changes or other visual information
Reading, writing and presenting text, symbolic representation, tables, graphs and diagrams	Use could be made of ICT, enlarged text, alternative paper and/or print colour and/or practical helpers for learners with visual impairment, specific learning difficulties and physical disabilities
Process information using calculations	Use could be made of practical helpers for learners with specific cognitive difficulties (eg dyscalculia)
Draw a valid conclusion, giving explanations and making generalisation/predictions	Use could be made of practical helpers for learners with specific cognitive difficulties or autism

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Appendix 1: Further information on Units in the Course

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 signalling 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

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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.

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Cells and Proteins

The **Mandatory Course key areas** are from the *Course Assessment Specification*. Activities in the **Suggested learning activities** are not mandatory. This offers examples of suggested activities, from which you could select a range of suitable activities. It is not expected that all will be covered. Centres may also devise their own learning activities. **Exemplification of key areas** is not mandatory. It provides an outline of the level of demand and detail of the key areas.

In the **Suggested learning activities**, there are references to the use of case studies. These should be seen as a suggested approach to teaching and learning and not confused with the use of case study as a method of Course assessment. These case studies should make learning active, challenging and enjoyable and identify for the learner the Course content and skills that will be developed. Case studies should be developed in such a way that learners have the opportunity to select activities, where appropriate, and present the opportunity to pursue further study. Case studies need not necessarily be restricted to one Unit but could include biology drawn from different Units.

Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
1 Laboratory techniques for biologists (a) Health and safety Identifying and controlling hazards and assessing risk. The use of physical or biological control measures including the use of personal protective equipment.	Standard laboratory rules and familiarity with risk assessment.	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. Biological control includes using a more suitable strain of microorganism eg less virulent.
(b) Liquids and solutions Dilution series are often linear or log. Standard curves, measurement and determination of an unknown concentration. The use of buffers to	Practice measuring and making solutions and using buffers before embarking upon important experimentation. Use a colorimeter or spectrophotometer	Use of cylinders, pipettes, burettes, autopipettors and syringes. pH can be measured using a meter or an indicator. The concentration of a pigmented compound can be quantified using a

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
maintain and control pH.	to calibrate a known solution and determine an unknown using eg Bradford reagent.	colorimeter.
(c) Separation techniques Separation techniques using solubility, size, shape and charge, including centrifugation, paper, thin layer and affinity chromatography, protein electrophoresis, separation of proteins and iso-electric points.	Use protein electrophoresis to identify different muscle proteins. Determine the iso-electric point of a soluble protein such as casein.	Centrifugation to separate pellet and supernatant of differing solubility. 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.
(d) Antibody techniques Detection and identification of specific proteins. Immunoassay techniques use antibodies linked to reporter enzymes. Use of labelled antibodies in protein blotting and immunohistochemical staining of tissue. Creation of monoclonal antibodies.	Use of monoclonal antibodies in the diagnosis and detection of disease. Use the ELISA technique to identify the presence of specific antigens.	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. Labelling of antibodies in blotting and immunohistochemical staining of tissue. To produce stocks of a particular antibody, hybridomas are formed by fusion of a B lymphocyte with a myeloma cell using polyethylene glycol (PEG).
(e) Microscopy Use of bright field and fluorescence	Refresh skills in the use of microscopes and making slides. Discuss the ethics of	Use of bright field to examine whole organisms, parts of organisms or thin

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
microscopy. Haemocytometers and flow cytometry.	dissection in an educational context.	sections of dissected tissue. Haemocytometers and flow cytometry. Fluorescence microscopy allows particular protein structures to be visualised.
(f) Cell culture and aseptic technique Use of explants or cells in inoculum. Estimation of viable and total cell counts. Lifetime of primary cell lines and cancer cell lines. The need for complex media for animal and plant cell culture.	Culture bacterial, yeast and algal cells using aseptic technique. Use a haemocytometer to make an estimate of cell count.	Sterilisation of containers, equipment and materials. Disinfection of working area. Culture media contain requirements of the cells. Viable and total cell counts. Complex media containing growth factors from serum for animal cell lines.
2 Proteins (a) Proteomics The proteome is larger than the genome due to RNA splicing and post-translational modification. As a result of gene expression not all genes are expressed as proteins in a particular cell.		The proteome is the entire set of proteins expressed by a genome. While DNA sequencing and microarray technology allow the routine analysis of the genome and transcriptome, the analysis of the proteome is far more complex.
(b) Protein structure, binding and conformational change		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.

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
(i) Amino acid sequence determines protein structure Primary sequence. The main classes of R groups and interactions in secondary and tertiary structure. Influence of temperature and pH on R group interactions. Prosthetic groups. Quaternary structure.	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. Primary structure comparisons of enzymes from different evolutionary backgrounds — alcohol dehydrogenase from different organisms. Post-translational modification and activity in trypsinogen and trypsin.	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 side chains) of the 20 amino acids based on functional group: positively charged; negatively charged; polar; hydrophobic; other. Individual names or structures not required. 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.

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
(ii) Hydrophobic and hydrophilic interactions influence the location of cellular proteins. The fluid mosaic model. The role of R groups in determining the distribution of soluble, globular, integral membrane and peripheral membrane proteins.	Look at history of evidence-based models of membrane structure as an example of refinement of scientific ideas.	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 Involvement of R groups in ligand binding. Proteins and DNA binding interactions including nucleosomes and transcription regulation.		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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
		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 Change in conformation causes a functional change in the protein. Substrate binding and induced fit. Activation energy, allosteric enzymes, positive and negative modulators and cooperativity in the binding and release of oxygen in haemoglobin.	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. Analyse haemoglobin dissociation curves.	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. 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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
		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.
(v) Reversible binding of phosphate and control of conformation The addition or removal of phosphate from R groups, reversible conformational changes and the regulation of the activity of proteins. Protein kinases, protein phosphatases and ATPases. Phosphorylation of myosin and its interaction with actin.	Muscle contraction experiment using ATP. An opportunity to focus on experimental design associated with pilot studies, measurement accuracy, sample size and replication.	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.
(c) Membrane proteins Movement of molecules across		Specific transmembrane proteins, which act as channels or transporters, control

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membranes. Phospholipid bilayer as a barrier to ions and most uncharged polar molecules. Transmembrane proteins including channel proteins, and transporter proteins. Gated channels, ligand gated channels and voltage gated channels. Substrate transport including facilitated and active transport.	CFTR, mutation and cystic fibrosis.	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.
(i) Signal transduction Signal transduction connects extracellular chemical signals to intracellular responses; activation of enzyme or G proteins, a change in uptake or secretion of molecules, rearrangement of the cytoskeleton or activation of proteins that regulate gene transcription.		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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
		regulate gene transcription.
(ii) Ion transport pumps and generation of ion gradients The mechanism and functions of the sodium potassium pump.		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 the sodium potassium pump (Na/K-ATPase) 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).
(iii) Ion channels and nerve transmission The pathway from signal molecules and	Daphnia heart rate investigation. The action of chemical agonists can be	Nerve transmission is a wave of depolarisation of the resting potential of a

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
depolarization through to restoring resting potential including the role of ligand and voltage gated channels.	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.	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.
(d) Detecting and amplifying an environmental stimulus Photoreceptor protein systems. Bacteriorhodopsin in archaea and photosynthetic pigments in plants both absorb light and generate potential differences which drives ATP synthase. Photoreceptor retinal in animals and signal amplification in cone and rod cells and the role of opsins.	Investigate vision experimentally. Eyes, in which the light sensitive cells are grouped into organized structures for vision, appear to be give an evolutionary	Photoreceptor protein systems 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 within protein systems 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,

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
	advantage; eyes are found in only six animal phyla yet are present in 95% of all animal species. Fish eye dissection.	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 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.
(e) Communication within multicellular organisms (i) Coordination Multicellular organisms achieve coordination through extracellular signalling molecules, receptors and responses. Different cell types may show a tissue specific response to the same signal.		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 signals can be detected by receptor molecules in the nucleus. The role		Hydrophobic signalling molecules include the thyroid hormone thyroxine and steroid hormones. Hydrophobic signals can pass through membranes so their receptor

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
of thyroid hormone and thyroxine on transcription of the gene for Na/K-ATPase in changing metabolic rate. Steroid hormones activate transcription by binding to receptor proteins which act as transcription factors.	Case study of thyroid disorders. Case study of sex hormone disorders.	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/K-ATPase. When thyroxine binds to the receptor protein, conformational change prevents the protein binding to the DNA allowing transcription of the gene for Na/KATPase resulting in an increase in 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.
Hydrophilic signals and transduction Hydrophilic signalling molecules include peptide hormones and neurotransmitters Binding of peptide hormones insulin and ADH to receptors and the cellular responses including GLUT4 and aquaporin 2, Diabetes type 1, 2 and insipidus as examples of failure to produce the		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.

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
hormone or loss of receptor function.	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.	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.
(f) Protein control of cell division (i) Cell division requires the remodelling of the cell's cytoskeleton Structure, composition and role of the cytoskeleton in cells to include the structure and synthesis of microtubules	Consider the effects of colchicine and paclitaxel on the 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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
and their role in cell division.		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.
(ii) The cell cycle Cell cycle consists of interphase and mitosis. G1, S and G2 phases of interphase. M phase consists of prophase, metaphase, anaphase and telophase followed by cytokinesis. The role of spindle fibres. Changes to the cell cycle can result in degenerative diseases or tumour formation.	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.	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 G1 followed by an S phase where the cell continues to grow and copies its chromosomes in preparation for mitosis and a further G2 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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
		chromatids and formation of daughter nuclei. Cytokinesis as the separation of the cytoplasm into daughter cells.
(iii) Control of the cell cycle Progression through the cell cycle is regulated by checkpoints at G1, G2 and metaphase. Cells can enter a non-dividing state called the G0 phase if no go ahead signal is received at the G1 checkpoint. The role of cyclins, kinases, cyclin-dependent kinases, and the importance of phosphorylation of retinoblastoma protein in the G1 checkpoint. The role of proteins including p53 in response to DNA damage resulting in DNA repair, cell cycle arrest or cell death.	Use an online 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.	Checkpoints are critical control points where stop and go ahead signals regulate the cycle. For many cells the G1 checkpoint is the most important. If a go ahead signal is not reached at the G1 checkpoint the cell switches to a non-dividing state called the G0 phase. As the cell size increases during G1 cyclin proteins accumulate and combine with kinases to form regulatory protein molecules known as cyclin-dependent 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 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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
		DNA repair, arrest the cell cycle or cause cell death.
(iv) Control of apoptosis Programmed cell death (apoptosis) is triggered by signals that activate DNAase and proteinases (caspases). Role of lymphocytes and p53 in cell death as examples of intracellular or extracellular cell death pathways.	Consider apoptosis in development of tetrapod limbs Research the challenges in overcoming apoptosis in maintaining animal cell culture lines.	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 out with 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.

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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.

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

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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.

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Organisms and Evolution

The **Mandatory Course key areas** are from the *Course Assessment Specification*. Activities in the **Suggested learning activities** are not mandatory. This offers examples of suggested activities, from which you could select a range of suitable activities. It is not expected that all will be covered. Centres may also devise their own learning activities. **Exemplification of key areas** is not mandatory. It provides an outline of the level of demand and detail of the key areas.

In the **Suggested learning activities**, there are references to the use of case studies. These should be seen as a suggested approach to teaching and learning and not confused with the use of case study as a method of Course assessment. These case studies should make learning active, challenging and enjoyable and identify for the learner the Course content and skills that will be developed. Case studies should be developed in such a way that learners have the opportunity to select activities, where appropriate, and present the opportunity to pursue further study. Case studies need not necessarily be restricted to one Unit but could include biology drawn from different Units.

Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
1 Field techniques for biologists (a) Health and safety Hazards and risks associated with fieldwork, such as terrain, weather conditions and isolation must be assessed.	Discuss standard rules for fieldwork safety	Fieldwork may involve a wider range of hazards compared with working in the laboratory.
(b) Sampling of wild organisms The chosen technique, such as point count, transects or remote detection, must be appropriate to the species being sampled, to include: quadrats, capture techniques, camera traps, scat sampling. Appropriate random, systematic and stratified sampling.	Participate in fieldwork. Identification of sample using guides and keys. Awareness of protected species in Scotland.	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. Quadrats of suitable size and shape are used for slow-moving organisms; capture techniques for mobile species. Elusive species can be sampled directly using

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
		camera traps or an indirect method such as scat sampling.
(c) Identification and taxonomy Methods of identification to include: using expertise, classification guides, keys or laboratory analysis of DNA, protein or other molecules. The concept of taxonomic groupings. Familiarity with taxonomic groupings allows predictions and inferences to be made between the biology of an organism and better-known (model) organisms. Classification of life into the three domains - archaea, bacteria and eukaryote. The plant kingdom has major divisions - mosses, liverworts, ferns, gymnosperms and angiosperms. The animal kingdom is divided into phyla including Chordate, Arthropoda, Nematoda, Platyhelminthes and Mollusca.	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 woodland. 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.	Identification of a sample can be made. The classification of life according to relatedness is central to biological understanding. Genetic evidence reveals relatedness obscured by divergent or convergent evolution. 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).
(d) Monitoring populations The use of information on species abundance to assess environmental impact. Method of mark and recapture to estimate population size (N = (MC)/R).	Identify relevant indicator species to classify a habitat using the British National Vegetation Classification.	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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
Effective and ethical methods of marking to include banding, tagging, surgical implantation, painting and hair clipping.	Carry out a mark and recapture experiment using a wild species or, alternatively, using school pupils to estimate the total school roll.	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 The method of marking and subsequent observation must be effective and should also minimize the impact on the study species.
(e) Measuring and recording animal behaviour Ethograms and time sampling to compare the behaviour of different individuals of a species.	Use an ethogram and time sampling to compare the behaviour of different individuals of a species.	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 Organisms (a) Evolution (i) Drift and selection Processes of evolution, natural selection, sexual selection and genetic drift. Mutations can be harmful, neutral or beneficial and give rise to variation.		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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
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.		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. 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.
(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.	

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
(iii) Co-evolution and the Red Queen Hypothesis A change in the traits of one species acts as a selection pressure on the other species. Co-evolutionary 'arms race' between a parasite and host as an example of the Red Queen Hypothesis.	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.	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 The co-evolutionary 'arms race' between a parasite and host is known as the Red Queen Hypothesis 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.
(b) Variation and sexual reproduction (i) 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. Benefits outweigh disadvantages due to increase in genetic variation in the population.	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'.	Compared to asexual reproduction, sexual reproduction appears to have two disadvantages. First, half of the population is 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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
Successful asexual reproduction strategies – to include examples of vegetative cloning, parthenogenesis and horizontal gene transfer.	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).	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.
(ii) Meiosis forms variable gametes Increased variation through the production of haploid gametes by meiosis - meiosis I, meiosis II, gamete mother cell, chromosome, chromatid, homologous pairs, crossing over, chiasmata,	Use microscopy to examine gamete formation or gametes in plants or invertebrates.	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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
independent assortment, linked genes and frequency of recombination. 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.	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. Independent assortment occurs as a result of meiosis I with homologous chromosomes being separated irrespective of their maternal and paternal origin.
(iii) Sex determination Sex determination in mammals and Drosophila, sex ratio and resource availability. Environmental factors can affect sex determination. Change of sex through size, competition or parasitic infection. Hermaphrodites. Sex linked patterns of inheritance in carrier females and affected males in terms of gene products.	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.	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 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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
Random inactivation on X chromosomes in females prevents a double dose of gene products. Half of the cells in any tissue will have a working copy of the gene in question therefore carriers remain unaffected by any deleterious mutations.	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.	some species the sex ratio of offspring can be adjusted in response to resource availability. 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.
(c) Sex and behaviour (i) Sexual investment Comparison of investment in sperm and egg production – number and energy store; greater investment by females. Problems and solutions of sex for sessile organisms. Parental investment, optimal reproduction	Investigate foraging/pollinating behaviour of insects at flowers. Investigate a range of reproductive strategies using examples such as naked mole rats.	Parental investment is costly but increases the probability of production and survival of young. Simplistic Various reproductive strategies have evolved ranging from polygamy to monogamy.

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
and reproductive strategies in terms of the number and quality of current offspring versus potential future offspring. Classification of parental investment into discrete r-selected and K-selected organisms does not reflect continuous range of life history strategies.		
(ii) Courtship Sexual dimorphism as a product of sexual selection. Male-male rivalry: large size, weaponry, sneakers. 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 process that occurs during a critical time period in young birds, may influence mate choice later in life. Females are generally inconspicuous, reversed in some species. Female choice: assessing male fitness, Fitness can be in terms of good genes and low parasite burden. Lekking species. In lekking species, alternative successful strategies of dominant and satellite males.	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.	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.
(d) Parasitism (i) The parasite niche Parasites tend to have a narrow niche as they have high host specificity and may	Research the niche of *C. difficile* and the use of faecal transplants.	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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
lead to parasites which are degenerate. They are lacking in structures and organs found in other organisms. Ectoparasite and endoparasite niches. Life cycles, definitive hosts, intermediate hosts and vectors. Fundamental and realised niches, interspecific competition and competitive exclusion.		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. As the host provides so many of the parasite's needs, many parasites are degenerate. 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. 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,

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
		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 potential of a parasite to cause harm to a host. 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	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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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
parasite population. The most successful parasites have efficient modes of transmission and rapid rates of evolution.		
(iii) Immune response to parasites Non-specific defenses in mammals: physical barriers, chemical secretions, inflammatory response, phagocytes, natural killer cells destroying abnormal cells. Mechanism of specific cellular defenses in mammals: apoptosis, phagocytosis, T lymphocytes, B lymphocytes and immunological memory cells. Epidemiology and herd immunity. The herd immunity threshold is the density of resistant hosts in the population required to prevent an epidemic. Endoparasites and antigenic variation.	Use a statistical test to confirm or refute the significance of results of an epidemiological study into disease.	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. 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.
(iv) Macroparasitic life cycles Macroparasites: endoparasitic amoebas,	Consider the ecology, evolution, reproduction and physiology of a selected	Ectoparasites and endoparasites of the main body cavities, such as the gut, are

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
platyhelminths, nematodes. Ectoparasitic arthropods. Ectoparasitic Transmission through direct contact, consumption of secondary hosts or endoparasitic transmission by vectors. Schistosomiasis and malaria.	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.	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.
(v) Microparasites Microparasites: viruses and bacteria. Human diseases: influenza, HIV/AIDS and tuberculosis. Viral structure and replication. Antigenicity. RNA retroviruses and reverse transcriptase.	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.	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.

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
(vi) Challenges in treatment and control Treatment and control of parasites. Challenges in the design of vaccines and drugs including rapid antigen change and similarities between host and parasite metabolism. Sanitation and vector control: overcrowding, natural disasters, tropical climates, developing countries, child mortality.	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.	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.

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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.

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Investigative Biology

The **Mandatory Course key areas** are from the *Course Assessment Specification*. Activities in the **Suggested learning activities** are not mandatory. This offers examples of suggested activities, from which you could select a range of suitable activities. It is not expected that all will be covered. Centres may also devise their own learning activities. **Exemplification of key areas** is not mandatory. It provides an outline of the level of demand and detail of the key areas.

In the **Suggested learning activities**, there are references to the use of case studies. These should be seen as a suggested approach to teaching and learning and not confused with the use of case study as a method of Course assessment. These case studies should make learning active, challenging and enjoyable and identify for the learner the Course content and skills that will be developed. Case studies should be developed in such a way that learners have the opportunity to select activities, where appropriate, and present the opportunity to pursue further study. Case studies need not necessarily be restricted to one Unit but could include biology drawn from different Units.

Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
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. Scientific ideas only become accepted once they have been checked independently;	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	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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
	the impact of mental inertia on the advancement of science.	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. One-off results are treated with caution.
(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. Critical evaluation of science coverage in the wider 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*).	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. Increasing the public understanding of science and the issue of misrepresentation of science in the media.
(c) Scientific ethics Importance of integrity and honesty – unbiased presentation of results, citing and providing references, avoiding plagiarism. Minimising harm in animal studies. 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	Discuss excerpts from Ben Goldacre's *Bad Science*. Use an online 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	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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
can all influence scientific research.	locate your source material. Discuss the implications of Russell and Burch's 3Rs on school-based animal studies. 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.	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. 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.
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.	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.	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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
		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.
(b) Variables Controlling and or monitoring confounding variables, including randomized block design. Discrete and continuous variables give rise to qualitative, quantitative or ranked data.	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.	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.
(c) Experimental design Controls, dependent and independent variables. The use and limitations of simple and multifactorial experimental designs	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	Experiments involve the manipulation of the independent variable by the investigator. The experimental treatment group is compared to a control.

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
and observational studies.	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. 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.	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. 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.
(d) Controls The use of positive and negative controls.	Design an experiment with positive and negative controls, such as a laboratory investigation using an enzyme.	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.
(e) Sampling Determining a representative sample of a population.	Consider aspects of sampling in investigating heart rate in Daphnia or contraction of muscle due to ATP. Is	Where it is impractical to measure every individual, a representative sample of the population is selected. The extent of the

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
The use of random, systematic, and stratified sampling.	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.	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. Measuring a sample of individuals to obtain a true value. Repeating experiments as a whole to check the reliability of results.	Determine the precision of a measuring procedure by repeated measurements and the accuracy of a measuring procedure by calibration against a known standard. Use measures of central tendency to measure the extent of natural variation in samples.	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. 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.

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
	Check the consistency of results by repeating experiments, pooling results or reference to scientific literature.	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.
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.		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.
(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		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

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
size on representative sampling.		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.
(c) Evaluating data analysis The appropriate use of graphs, mean, median, mode, standard deviation and range in interpreting data. Use of error bars and confidence intervals to determine significance of results.	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.	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, standard deviation 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.
(d) Evaluating conclusions	Compare and evaluate a variety of	In evaluating conclusions, reference

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Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
Conclusions should refer to the aim and 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.	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).	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.

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Appendix 2: Reference documents

The following reference documents will provide useful information and background.

- Assessment Arrangements (for disabled candidates and/or those with additional support needs) — various publications are available on SQA's website at: www.sqa.org.uk/sqa//14977.html.
- Building the Curriculum 4: Skills for Learning, Skills for Life and Skills for Work
- Building the Curriculum 5: A Framework for Assessment
- Course Specifications
- Design Principles for National Courses
- Guide to Assessment
- Overview of Qualification Reports
- Principles and practice papers for curriculum areas
- *SCQF Handbook: User Guide* and SCQF level descriptors
- SQA Skills Framework: Skills for Learning, Skills for Life and Skills for Work
- Skills for Learning, Skills for Life and Skills for Work: Using the Curriculum Tool
- Coursework Authenticity: A Guide for Teachers and Lecturers

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Administrative information

Published: April 2013 (draft version 1.0)

Superclass: to be advised

History of changes to Advanced Higher draft Course/Unit Support Notes

Course details	Version	Description of change	Authorised by	Date

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