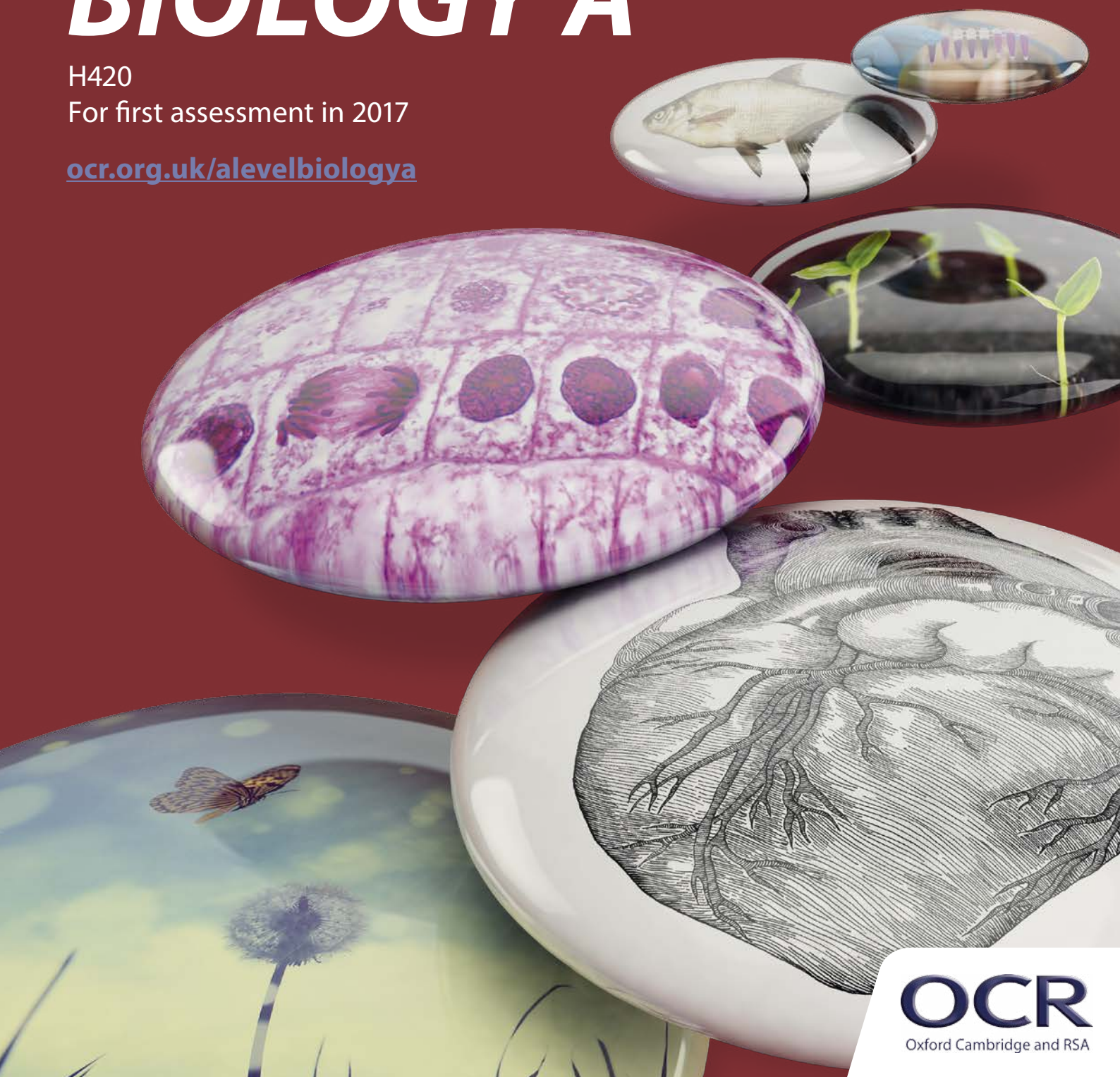
Accredited

A LEVEL
Specification

BIOLOGY A

H420
For first assessment in 2017

ocr.org.uk/alevelbiologya



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We will inform centres about any changes to the specification. We will also publish changes on our website. The latest version of our specification will always be the one on our website (ocr.org.uk) and this may differ from printed versions.

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Contents

Introducing…
A Level Biology A (from September 2015)

This specification allows teachers to adopt a flexible approach to the delivery of A Level Biology. The course has been designed to enable centres to deliver the content modules (Modules 2–6) using the framework provided, or to design a customised course. Practical work undertaken to support teaching of the content will serve to cover the requirements of the practical skills module (Module 1), which is assessed in the written examinations and through the Practical Endorsement.

The specification is divided into topics, each containing different key concepts of biology. Throughout the specification, cross-references indicate the relevance of individual learning outcomes to the mathematical and practical criteria that are embedded in the assessments.

This specification incorporates the Ofqual GCE Subject Level Conditions and Requirements for Biology.

Meet the team

We have a dedicated team of people working on our A Level Biology qualifications.

Find out more about our Biology team at **ocr.org.uk/scienceteam**

If you need specialist advice, guidance or support, get in touch as follows:

- **01223 553998**
- **scienceGCE@ocr.org.uk**
- **@OCR_science**

Teaching and learning resources

We recognise that the introduction of a new specification can bring challenges for implementation and teaching. Our aim is to help you at every stage and we're working hard to provide a practical package of support in close consultation with teachers and other experts, so we can help you to make the change.

Designed to support progression for all

Our resources are designed to provide you with a range of teaching activities and suggestions so you can select the best approach for your particular students. You are the experts on how your students learn and our aim is to support you in the best way we can.

We want to…

- Support you with a body of knowledge that grows throughout the lifetime of the specification
- Provide you with a range of suggestions so you can select the best activity, approach or context for your particular students.
- Make it easier for you to explore and interact with our resource materials, in particular to develop your own schemes of work.
- Create an ongoing conversation so we can develop materials that work for you.

Plenty of useful resources

You'll have four main types of subject-specific teaching and learning resources at your fingertips:

- Delivery Guides
- Transition Guides
- Topic Exploration Packs
- Lesson elements.

Along with subject-specific resources, you'll also have access to a selection of generic resources that focus on skills development and professional guidance for teachers.

Skills Guides – we've produced a set of Skills Guides that are not specific to Biology, but each covers a topic that could be relevant to a range of qualifications – for example, communication, legislation and research. Download the guides at **ocr.org.uk/skillsguides**

Active Results – a free online results analysis service to help you review the performance of individual students or your whole school. It provides access to detailed results data, enabling more comprehensive analysis of results in order to give you a more accurate measurement of the achievements of your centre and individual students. For more details refer to **ocr.org.uk/activeresults**

Professional development

Take advantage of our improved Professional Development Programme, designed with you in mind. Whether you want to come to face-to-face events, look at our new digital training or search for training materials, you can find what you're looking for all in one place at the CPD Hub.

An introduction to the new specifications:

We'll be running events to help you get to grips with our A Level Biology A qualification.

These events are designed to help prepare you for first teaching and to support your delivery at every stage.

Watch out for details at **cpdhub.ocr.org.uk**

To receive the latest information about the training we'll be offering, please register for A Level email updates at **ocr.org.uk/updates**

1 Why choose an OCR A Level in Biology A?

1a. Why choose an OCR qualification?

Choose OCR and you've got the reassurance that you're working with one of the UK's leading exam boards. Our new A Level in Biology A course has been developed in consultation with teachers, employers and higher education to provide students with a qualification that's relevant to them and meets their needs.

We're part of the Cambridge Assessment Group, Europe's largest assessment agency and a department of the University of Cambridge. Cambridge Assessment plays a leading role in developing and delivering assessments throughout the world, operating in over 150 countries.

We work with a range of education providers, including schools, colleges, workplaces and other institutions in both the public and private sectors. Over 13,000 centres choose our A levels, GCSEs and vocational qualifications including Cambridge Nationals, Cambridge Technicals and Cambridge Progression.

Our Specifications

We believe in developing specifications that help you bring the subject to life and inspire your students to achieve more.

We've created teacher-friendly specifications based on extensive research and engagement with the teaching community. They're designed to be straightforward and accessible so that you can tailor the delivery of the course to suit your needs. We aim to encourage learners to become responsible for their own learning, confident in discussing ideas, innovative and engaged.

We provide a range of support services designed to help you at every stage, from preparation through to the delivery of our specifications. This includes:

- A wide range of high-quality creative resources including:
  - delivery guides
  - transition guides
  - topic exploration packs
  - lesson elements
  - …and much more.
- Access to Subject Specialists to support you through the transition and throughout the lifetime of the specifications.
- CPD/Training for teachers including face-to-face events to introduce the qualifications and prepare you for first teaching.
- Active Results – our free results analysis service to help you review the performance of individual students or whole schools.
- ExamCreator – our new online past papers service that enables you to build your own test papers from past OCR exam questions.

All A level qualifications offered by OCR are accredited by Ofqual, the Regulator for qualifications offered in England. The accreditation number for OCR's A Level in Biology A is (601/4260/1)

1b. Why choose an OCR A Level in Biology A?

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We appreciate that one size doesn't fit all so we offer two suites of qualifications in each science:

Biology A – Provides a flexible approach to teaching. The specification is divided into topics, each covering different key concepts of biology. Teaching of practical skills is integrated with the theoretical topics and they are assessed through the written papers. For A level only, the Practical Endorsement will also support the development of practical skills.

Biology B (Advancing Biology) (a new course for OCR) – Learners study biology using a context-based approach. Ideas are introduced within relevant and interesting settings which help learners to anchor their conceptual knowledge of the range of biological topics required at GCE level. Practical skills are embedded within the specification and learners are expected to carry out practical work in preparation for a written examination that will specifically test these skills.

All of our specifications have been developed with subject and teaching experts. We have worked in close consultation with teachers and representatives from Higher Education (HE) with the aim of including up-to-date relevant content within a framework that is interesting to teach and administer within all centres (large and small).

Our new A Level in Biology A qualification builds on our existing popular course. We've based the redevelopment of our A level sciences on an understanding of what works well in centres large and small and have updated areas of content and assessment where stakeholders have identified that improvements could be made. We've undertaken a significant amount of consultation through our science forums (which include representatives from learned societies, HE, teaching and industry) and through focus groups with teachers. Our papers and specifications have been trialled in centres during development to make sure they work well for all centres and learners.

The content changes are an evolution of our legacy offering and will be familiar to centres already following our courses, but are also clear and logically laid out for centres new to OCR, with assessment models that are straightforward to administer. We have worked closely with teachers and HE representatives to provide high quality support materials to guide you through the new qualifications.

Aims and learning outcomes

OCR's A Level in Biology A specification aims to encourage learners to:

- develop essential knowledge and understanding of different areas of the subject and how they relate to each other
- develop and demonstrate a deep appreciation of the skills, knowledge and understanding of scientific methods
- develop competence and confidence in a variety of practical, mathematical and problem solving skills
- develop their interest in and enthusiasm for the subject, including developing an interest in further study and careers associated with the subject
- understand how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society (as exemplified in 'How Science Works' (HSW)).

1c. What are the key features of this specification?

Our A Level in Biology A specification is designed with a content-led approach and provides a flexible way of teaching. The specification:

- retains and refreshes the popular topics from the legacy OCR Biology qualification (H421)
- is laid out clearly in a series of teaching modules with additional guidance added where required to clarify assessment requirements
- is co-teachable with the AS level
- embeds practical requirements within the teaching modules
- identifies Practical Endorsement requirements and how these can be integrated into teaching of content (see Section 5g)
- exemplifies the mathematical requirements of the course (see Section 5e)
- highlights opportunities for the introduction of key mathematical requirements (see Section 5e and the additional guidance column for each module) into your teaching
- identifies, within the Additional guidance column how the skills, knowledge and understanding of How Science Works (HSW) can be incorporated within teaching.

Teacher support

The extensive support offered alongside this specification includes:

- **delivery guides –** providing information on assessed content, the associated conceptual development and contextual approaches to delivery
- **transition guides –** identifying the levels of demand and progression for different key stages for a particular topic and going on to provide links to high quality resources and 'checkpoint tasks' to assist teachers in identifying learners 'ready for progression'
- **lesson elements –** written by experts, providing all the materials necessary to deliver creative classroom activities
- **Active Results** (see Section 1a)
- **ExamCreator** (see Section 1a)
- **mock examinations service –** a free service offering a practice question paper and mark scheme (downloadable from a secure location).

Along with:

- Subject Specialists within the OCR science team to help with course queries
- teacher training
- *Science Spotlight* (our termly newsletter)
- OCR Science community
- a consultancy service (to advise on Practical Endorsement requirements)
- Practical Skills Handbook
- Maths Skills Handbook.

1d. How do I find out more information?

Whether new to our specifications, or continuing on from our legacy offerings, you can find more information on our webpages at: **www.ocr.org.uk**

Visit our subject pages to find out more about the assessment package and resources available to support your teaching. The science team also release a termly newsletter *Science Spotlight* (despatched to centres and available from our subject pages).

You can contact the Science Subject Specialists: **ScienceGCE@ocr.org.uk**, 01223 553998

Join our Science community: **http://social.ocr.org.uk/**

Check what CPD events are available: **www.cpdhub.ocr.org.uk**

Follow us on Twitter: **@ocr_science**

2 The specification overview

2a. Overview of A Level in Biology A (H420)

Learners must complete all components (01, 02, 03 and 04).

Content Overview	Assessment Overview	
Content is split into six teaching modules: • Module 1 – Development of practical skills in biology • Module 2 – Foundations in biology • Module 3 – Exchange and transport • Module 4 – Biodiversity, evolution and disease • Module 5 – Communication, homeostasis and energy • Module 6 – Genetics, evolution and ecosystems Component 01 assesses content from modules 1, 2, 3 and 5. Component 02 assesses content from modules 1, 2, 4 and 6. Component 03 assesses content from all modules (1 to 6).	Biological processes (01) 100 marks 2 hour 15 minutes written paper	**37%** of total A level
	Biological diversity (02) 100 marks 2 hour 15 minutes written paper	**37%** of total A level
	Unified biology (03) 70 marks 1 hour 30 minutes written paper	**26%** of total A level
	Practical endorsement in biology (04)* (non exam assessment)	**Reported separately** (see section 5g)

*Details to be confirmed by Ofqual.

All components include synoptic assessment.

2b. Content of A Level in Biology A (H420)

The A Level in Biology A specification content is divided into six teaching modules and each module is further divided into key topics. Each module is introduced with a summary of the biology it contains and each topic is also introduced with a short summary text. The assessable content is divided into two columns: **Learning outcomes** and **Additional guidance**.

The Learning outcomes may all be assessed in the examinations (with the exception of some of the skills in section **1.2** which will be assessed directly through the Practical Endorsement). The Additional guidance column is included to provide further advice on delivery and the expected skills required from learners.

References to HSW (Section 5d) are included in the guidance to highlight opportunities to encourage a wider understanding of science.

The mathematical requirements in section 5e, are also referenced by the prefix *M* to link the mathematical skills required for A Level Biology to examples of biology content where those mathematical skills could be linked to learning.

The specification has been designed to be co-teachable with the standalone AS Level in Biology A qualification. The first four modules comprise the AS Level in Biology A course and learners studying the A level continue with the content of modules 5 and 6. The internally assessed Practical Endorsement skills also form part of the full A level (see module 1.2).

A summary of the content for the A level course is as follows:

Module 1 – Development of practical skills in biology

1.1 Practical skills assessed in a written examination

1.2 Practical skills assessed in the practical endorsement

Module 2 – Foundations in biology

2.1.1 Cell structure

2.1.2 Biological molecules

2.1.3 Nucleotides and nucleic acids

2.1.4 Enzymes

2.1.5 Biological membranes

2.1.6 Cell division, cell diversity and cellular organisation

Module 3 – Exchange and transport

3.1.1 Exchange surfaces

3.1.2 Transport in animals

3.1.3 Transport in plants

Module 4 – Biodiversity, evolution and disease

4.1.1 Communicable diseases, disease prevention and the immune system

4.2.1 Biodiversity

4.2.2 Classification and evolution

Module 5 – Communication, homeostasis and energy

5.1.1 Communication and homeostasis

5.1.2 Excretion as an example of homeostatic control

5.1.3 Neuronal communication

5.1.4 Hormonal communication

5.1.5 Plant and animal responses

5.2.1 Photosynthesis

5.2.2 Respiration

Module 6 – Genetics, evolution and ecosystems

6.1.1 Cellular control

6.1.2 Patterns of inheritance

6.1.3 Manipulating genomes

6.2.1 Cloning and biotechnology

6.3.1 Ecosystems

6.3.2 Populations and sustainability.

Assessment of practical skills and the practical endorsement

Module 1 of the specification content relates to the practical skills learners are expected to gain throughout the course, which are assessed throughout the written examinations and also through the Practical Endorsement (see Section 5g).

Practical activities are embedded within the learning outcomes of the course to encourage practical activities in the classroom which contribute to the achievement of the Practical Endorsement (Section 5g) as well as enhancing learners' understanding of biological theory and practical skills.

Opportunities for carrying out activities that could count towards the Practical Endorsement are indicated throughout the specification. These are shown in the Additional guidance column as **PAG1** to **PAG11** (Practical Activity Group, see Section 5g). There are a wide variety of opportunities to assess **PAG12** throughout the qualification.

2c. Content of modules 1 to 6

Module 1: Development of practical skills in biology

The development of practical skills is a fundamental and integral aspect of the study of any scientific subject. These skills not only enhance learners' understanding of the subject but also serve as a suitable preparation for the demands of studying biology at a higher level.

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1.1 Practical skills assessed in a written examination

Practical skills are embedded throughout all the content of this specification.

Learners will be required to develop a range of practical skills throughout their course in preparation for the written examinations.

1.1.1 Planning

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	experimental design, including to solve problems set in a practical context	Including selection of suitable apparatus, equipment and techniques for the proposed experiment. Learners should be able to apply scientific knowledge based on the content of the specification to the practical context. HSW3
(b)	identification of variables that must be controlled, where appropriate	
(c)	evaluation that an experimental method is appropriate to meet the expected outcomes.	HSW6

1.1.2 Implementing

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how to use a wide range of practical apparatus and techniques correctly	As outlined in the content of the specification and the skills required for the Practical Endorsement. HSW4
(b)	appropriate units for measurements	*M0.1*
(c)	presenting observations and data in an appropriate format.	HSW8

1.1.3 Analysis

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	processing, analysing and interpreting qualitative and quantitative experimental results	Including reaching valid conclusions, where appropriate. HSW5
(b)	use of appropriate mathematical skills for analysis of quantitative data	Refer to Section 5e for a list of mathematical skills that learners should have acquired competence in as part of their course. HSW3
(c)	appropriate use of significant figures	*M1.1*
(d)	plotting and interpreting suitable graphs from experimental results, including:	
	(i) selection and labelling of axes with appropriate scales, quantities and units	*M3.2*
	(ii) measurement of gradients and intercepts.	*M3.3, M3.4, M3.5*

1.1.4 Evaluation

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how to evaluate results and draw conclusions	HSW6
(b)	the identification of anomalies in experimental measurements	
(c)	the limitations in experimental procedures	
(d)	precision and accuracy of measurements and data, including margins of error, percentage errors and uncertainties in apparatus	*M1.11*
(e)	the refining of experimental design by suggestion of improvements to the procedures and apparatus.	HSW3

1.2 Practical skills assessed in the practical endorsement

A range of practical experiences is a vital part of a learner's development as part of this course.

Learners should develop and practise a wide range of practical skills throughout the course as preparation for the Practical Endorsement, as well as for the written examinations.

The experiments and skills required for the Practical Endorsement will allow learners to develop and practise their practical skills, preparing learners for the written examinations.

Please refer to Section 5g (the Practical Endorsement) in this specification to see the list of practical experiences all learners should cover during their course. Further advice and guidance on the Practical Endorsement can be found in the Practical Skills Handbook.

1.2.1 Practical skills

	Learning outcomes	Additional guidance
	Practical work carried out throughout the course will enable learners to develop the following skills:	
Independent thinking		
(a)	apply investigative approaches and methods to practical work	Including how to solve problems in a practical context. HSW3
Use and application of scientific methods and practices		
(b)	safely and correctly use a range of practical equipment and materials	See Section 5g. Including identification of potential hazards. Learners should understand how to minimise the risks involved. HSW4
(c)	follow written instructions	
(d)	make and record observations/measurements	HSW8
(e)	keep appropriate records of experimental activities	See Section 5g.
(f)	present information and data in a scientific way	HSW8
(g)	use appropriate software and tools to process data, carry out research and report findings	*M3.1* HSW3
Research and referencing		
(h)	use online and offline research skills including websites, textbooks and other printed scientific sources of information	
(i)	correctly cite sources of information	The Practical Skills Handbook provides guidance on appropriate methods for citing information.
Instruments and equipment		
(j)	use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification.	See Section 5g. HSW4

1.2.2 Use of apparatus and techniques

	Learning outcomes	Additional guidance
	*Through use of the apparatus and techniques listed below, and a minimum of 12 assessed practicals (see Section 5g), learners should be able to demonstrate all of the practical skills listed within 1.2.1 and CPAC (Section 5g, **Table 2**) as exemplified through:*	
(a)	use of appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)	HSW4
(b)	use of appropriate instrumentation to record quantitative measurements, such as a colorimeter or potometer	HSW4
(c)	use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions	HSW4
(d)	use of a light microscope at high power and low power, including use of a graticule	HSW4
(e)	production of scientific drawings from observations with annotations	HSW8
(f)	use of qualitative reagents to identify biological molecules	HSW4
(g)	separation of biological compounds using thin layer/paper chromatography or electrophoresis	HSW4
(h)	safe and ethical use of organisms to measure: **(i)** plant or animal responses **(ii)** physiological functions	HSW4, HSW10
(i)	use of microbiological aseptic techniques, including the use of agar plates and broth	HSW4
(j)	safe use of instruments for dissection of an animal or plant organ	HSW4
(k)	use of sampling techniques in fieldwork	HSW4
(l)	use of ICT such as computer modelling, or a data logger to collect data, or use of software to process data.	HSW3, HSW4

Module 2: Foundations in biology

All living organisms have similarities in cellular structure, biochemistry and function. An understanding of these similarities is fundamental to the study of the subject.

This module gives learners the opportunity to use microscopy to study the cell structure of a variety of organisms. Biologically important molecules such as carbohydrates, proteins, water and nucleic acids are studied with respect to their structure and function. The structure and mode of action of enzymes in catalysing biochemical reactions is studied.

Membranes form barriers within, and at the surface of, cells. This module also considers the way in which the structure of membranes relates to the different methods by which molecules enter and leave cells and organelles.

The division and subsequent specialisation of cells is studied, together with the potential for the therapeutic use of stem cells.

Learners are expected to apply knowledge, understanding and other skills developed in this module to new situations and/or to solve related problems.

2.1 Foundations in biology

2.1.1 Cell structure

Biology is the study of living organisms. Every living organism is made up of one or more cells, therefore understanding the structure and function of the cell is a fundamental concept in the study of biology. Since Robert Hooke coined the phrase 'cells' in 1665, careful observation using microscopes has revealed details of cell structure and ultrastructure and provided evidence to support hypotheses regarding the roles of cells and their organelles.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the use of microscopy to observe and investigate different types of cell and cell structure in a range of eukaryotic organisms	To include an appreciation of the images produced by a range of microscopes, light microscope, transmission electron microscope, scanning electron microscope and laser scanning confocal microscope. HSW1, HSW7
(b)	the preparation and examination of microscope slides for use in light microscopy	Including the use of an eye piece graticule and stage micrometer. **PAG1** HSW4
(c)	the use of staining in light microscopy	To include the use of differential staining to identify different cellular components and cell types. **PAG1** HSW4, HSW5
(d)	the representation of cell structure as seen under the light microscope using drawings and annotated diagrams of whole cells or cells in sections of tissue	**PAG1**

(e)	the use and manipulation of the magnification formula	$magnification = \frac{image\ size}{object\ size}$ *M0.1, M0.2, M0.3, M1.1, M1.8, M2.2, M2.3, M2.4*
(f)	the difference between magnification and resolution	To include an appreciation of the differences in resolution and magnification that can be achieved by a light microscope, a transmission electron microscope and a scanning electron microscope. *M0.2, M0.3* HSW7, HSW8
(g)	the ultrastructure of eukaryotic cells and the functions of the different cellular components	To include the following cellular components and an outline of their functions: nucleus, nucleolus, nuclear envelope, rough and smooth endoplasmic reticulum (ER), Golgi apparatus, ribosomes, mitochondria, lysosomes, chloroplasts, plasma membrane, centrioles, cell wall, flagella and cilia. *M0.2*
(h)	photomicrographs of cellular components in a range of eukaryotic cells	To include interpretation of transmission and scanning electron microscope images.
(i)	the interrelationship between the organelles involved in the production and secretion of proteins	No detail of protein synthesis is required.
(j)	the importance of the cytoskeleton	To include providing mechanical strength to cells, aiding transport within cells and enabling cell movement. HSW2
(k)	the similarities and differences in the structure and ultrastructure of prokaryotic and eukaryotic cells.	**PAG1**

2.1.2 Biological molecules

The cells of all living organisms are composed of biological molecules. Proteins, carbohydrates and lipids are three of the key groups of biological macromolecules that are essential for life. A study of the structure of these macromolecules allows a better understanding of their functions in living organisms.

2

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	Where appropriate, this section should include diagrams to represent molecular structure and bonding.
(a)	how hydrogen bonding occurs between water molecules, and relate this, and other properties of water, to the roles of water for living organisms	A range of roles that relate to the properties of water, including solvent, transport medium, coolant and as a habitat **AND** roles illustrated using examples of prokaryotes and eukaryotes. HSW2, HSW8
(b)	the concept of monomers and polymers and the importance of condensation and hydrolysis reactions in a range of biological molecules	
(c)	the chemical elements that make up biological molecules	To include: C, H and O for carbohydrates C, H and O for lipids C, H, O, N and S for proteins C, H, O, N and P for nucleic acids
(d)	the ring structure and properties of glucose as an example of a hexose monosaccharide and the structure of ribose as an example of a pentose monosaccharide	To include the structural difference between an α- and a β-glucose molecule **AND** the difference between a hexose and a pentose monosaccharide.
(e)	the synthesis and breakdown of a disaccharide and polysaccharide by the formation and breakage of glycosidic bonds	To include the disaccharides sucrose, lactose and maltose.
(f)	the structure of starch (amylose and amylopectin), glycogen and cellulose molecules	HSW8
(g)	how the structures and properties of glucose, starch, glycogen and cellulose molecules relate to their functions in living organisms	HSW2, HSW8
(h)	the structure of a triglyceride and a phospholipid as examples of macromolecules	To include an outline of saturated and unsaturated fatty acids.
(i)	the synthesis and breakdown of triglycerides by the formation (esterification) and breakage of ester bonds between fatty acids and glycerol	

(j)	how the properties of triglyceride, phospholipid and cholesterol molecules relate to their functions in living organisms	To include hydrophobic and hydrophilic regions and energy content **AND** illustrated using examples of prokaryotes and eukaryotes. HSW2, HSW8
(k)	the general structure of an amino acid	
(l)	the synthesis and breakdown of dipeptides and polypeptides, by the formation and breakage of peptide bonds	
(m)	the levels of protein structure	To include primary, secondary, tertiary and quaternary structure **AND** hydrogen bonding, hydrophobic and hydrophilic interactions, disulfide bonds and ionic bonds. HSW8
(n)	the structure and function of globular proteins including a conjugated protein	To include haemoglobin as an example of a conjugated protein (globular protein with a prosthetic group), a named enzyme and insulin. An opportunity to use computer modelling to investigate the levels of protein structure within the molecule. **PAG10**
(o)	the properties and functions of fibrous proteins	To include collagen, keratin and elastin (no details of structure are required).
(p)	the key inorganic ions that are involved in biological processes	To include the correct chemical symbols for the following cations and anions: cations: calcium ions (Ca^{2+}), sodium ions (Na^{+}), potassium ions (K^{+}), hydrogen ions (H^{+}), ammonium ions (NH_4^{+}) anions: nitrate (NO_3^{-}), hydrogencarbonate (HCO_3^{-}), chloride (Cl^{-}), phosphate (PO_4^{3-}), hydroxide, (OH^{-}).
(q)	how to carry out and interpret the results of the following chemical tests: • biuret test for proteins • Benedict's test for reducing and non-reducing sugars • reagent test strips for reducing sugars • iodine test for starch • emulsion test for lipids	**PAG9** HSW3, HSW4, HSW5

(r)		quantitative methods to determine the concentration of a chemical substance in a solution	To include colorimetry and the use of biosensors (an outline only of the mechanism is required). **PAG5** HSW3, HSW4, HSW5
(s)	**(i)**	the principles and uses of paper and thin layer chromatography to separate biological molecules / compounds	To include calculation of retention (*Rf)* values.
	(ii)	practical investigations to analyse biological solutions using paper or thin layer chromatography.	For example the separation of proteins, carbohydrates, vitamins or nucleic acids. *M0.1, M0.2, M1.1, M1.3, M2.2, M2.3, M2.4* **PAG6** HSW2, HSW3, HSW4

2.1.3 Nucleotides and nucleic acids

Nucleic acids are essential to heredity in living organisms. Understanding the structure of nucleotides and nucleic acids allows an understanding of their roles in the storage and use of genetic information and cell metabolism.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the structure of a nucleotide as the monomer from which nucleic acids are made	To include the differences between RNA and DNA nucleotides, the identification of the purines and pyrimidines and the type of pentose sugar. An opportunity to use computer modelling to investigate nucleic acid structure. **PAG10**
(b)	the synthesis and breakdown of polynucleotides by the formation and breakage of phosphodiester bonds	
(c)	the structure of ADP and ATP as phosphorylated nucleotides	Comprising a pentose sugar (ribose), a nitrogenous base (adenine) and inorganic phosphates.
(d)	**(i)** the structure of DNA (deoxyribonucleic acid) **(ii)** practical investigations into the purification of DNA by precipitation	To include how hydrogen bonding between complementary base pairs (A to T, G to C) on two antiparallel DNA polynucleotides leads to the formation of a DNA molecule, and how the twisting of DNA produces its 'double-helix' shape. **PAG9** HSW3, HSW4
(e)	semi-conservative DNA replication	To include the roles of the enzymes helicase and DNA polymerase, the importance of replication in conserving genetic information with accuracy and the occurrence of random, spontaneous mutations. HSW8
(f)	the nature of the genetic code	To include the triplet, non-overlapping, degenerate and universal nature of the code and how a gene determines the sequence of amino acids in a polypeptide (the primary structure of a protein).
(g)	transcription and translation of genes resulting in the synthesis of polypeptides.	To include, the roles of RNA polymerase, messenger (m)RNA, transfer (t)RNA, ribosomal (r)RNA. HSW8

2.1.4 Enzymes

Metabolism in living organisms relies upon enzyme-controlled reactions. Knowledge of how enzymes function and the factors that affect enzyme action has improved our understanding of biological processes and increased our use of enzymes in industry.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the role of enzymes in catalysing reactions that affect metabolism at a cellular and whole organism level	To include the idea that enzymes affect both structure and function.
(b)	the role of enzymes in catalysing both intracellular and extracellular reactions	To include catalase as an example of an enzyme that catalyses intracellular reactions and amylase and trypsin as examples of enzymes that catalyse extracellular reactions.
(c)	the mechanism of enzyme action	To include the tertiary structure, specificity, active site, lock and key hypothesis, induced-fit hypothesis, enzyme-substrate complex, enzyme-product complex, product formation and lowering of activation energy. HSW1, HSW8
(d) **(i)**	the effects of pH, temperature, enzyme concentration and substrate concentration on enzyme activity	To include reference to the temperature coefficient (Q_{10}).
(ii)	practical investigations into the effects of pH, temperature, enzyme concentration and substrate concentration on enzyme activity	An opportunity for serial dilutions. M0.1, M0.2, M0.3, M1.1, M1.3, M1.11, M3.1, M3.2, M3.3, M3.5, M3.6 **PAG4** HSW1, HSW2, HSW4, HSW5, HSW6, HSW8.
(e)	the need for coenzymes, cofactors and prosthetic groups in some enzyme-controlled reactions	To include Cl^- as a cofactor for amylase, Zn^{2+} as a prosthetic group for carbonic anhydrase and vitamins as a source of coenzymes. **PAG4**
(f)	the effects of inhibitors on the rate of enzyme-controlled reactions.	To include competitive and non-competitive and reversible and non-reversible inhibitors with reference to the action of metabolic poisons and some medicinal drugs, and the role of product inhibition **AND** inactive precursors in metabolic pathways (covered at A level only). *M0.1, M0.2, M0.3, M1.1, M1.3, M1.11, M3.1, M3.2, M3.3, M3.5, M3.6* **PAG4** HSW1, HSW2, HSW4, HSW5, HSW6, HSW8

2.1.5 Biological membranes

Membranes are fundamental to the cell theory. The structure of the plasma membrane allows cells to communicate with each other. Understanding this ability to communicate is important as scientists increasingly make use of membrane-bound receptors as sites for the action of medicinal drugs.

Understanding how different substances enter cells is also crucial to the development of mechanisms for the administration of drugs.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the roles of membranes within cells and at the surface of cells	To include the roles of membranes as, • partially permeable barriers between the cell and its environment, between organelles and the cytoplasm and within organelles • sites of chemical reactions • sites of cell communication (cell signalling).
(b)	the fluid mosaic model of membrane structure and the roles of its components	To include phospholipids, cholesterol, glycolipids, proteins and glycoproteins **AND** the role of membrane-bound receptors as sites where hormones and drugs can bind. *M0.2* HSW1
(c) **(i)**	factors affecting membrane structure and permeability	To include the effects of temperature and solvents.
(ii)	practical investigations into factors affecting membrane structure and permeability	*M0.1, M0.2, M1.1, M1.2, M1.3, M1.6, M1.11, M3.1, M3.2, M3.3, M3.5, M3.6* **PAG8** HSW1, HSW2, HSW3, HSW4, HSW5, HSW6
(d) **(i)**	the movement of molecules across membranes	To include diffusion and facilitated diffusion as passive methods **AND** active transport, endocytosis and exocytosis as processes requiring adenosine triphosphate (ATP) as an immediate source of energy.
(ii)	practical investigations into the factors affecting diffusion rates in model cells	*M0.1, M0.2, M0.3, M1.1, M1.2, M1.3, M1.6, M1.11, M2.1, M3.1, M3.2, M3.3, M3.5, M3.6, M4.1* **PAG8** HSW1, HSW2, HSW3, HSW4, HSW5, HSW6

(e)	**(i)**	the movement of water across membranes by osmosis and the effects that solutions of different water potential can have on plant and animal cells	Osmosis to be explained in terms of a water potential gradient across a partially-permeable membrane. *M0.1, M0.2, M0.3, M1.1, M1.2, M1.3, M1.6, M1.10, M1.11, M2.1, M3.1, M3.2, M4.1* **PAG8** HSW1, HSW2, HSW3, HSW4, HSW5, HSW6
	(ii)	practical investigations into the effects of solutions of different water potential on plant and animal cells.	

2.1.6 Cell division, cell diversity and cellular organisation

During the cell cycle, genetic information is copied and passed to daughter cells. Microscopes can be used to view the different stages of the cycle.

In multicellular organisms, stem cells are modified to produce many different types of specialised cell.

Understanding how stem cells can be modified has huge potential in medicine.

To understand how a whole organism functions, it is essential to appreciate the importance of cooperation between cells, tissues, organs and organ systems.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the cell cycle	To include the processes taking place during interphase (G_1, S and G_2), mitosis and cytokinesis, leading to genetically identical cells. HSW8
(b)	how the cell cycle is regulated	To include an outline of the use of checkpoints to control the cycle.
(c)	the main stages of mitosis	To include the changes in the nuclear envelope, chromosomes, chromatids, centromere, centrioles, spindle fibres and cell membrane. HSW8
(d)	sections of plant tissue showing the cell cycle and stages of mitosis	To include the examination of stained sections and squashes of plant tissue and the production of labelled diagrams to show the stages observed. **PAG1**
(e)	the significance of mitosis in life cycles	To include growth, tissue repair and asexual reproduction in plants, animals and fungi. HSW2
(f)	the significance of meiosis in life cycles	To include the production of haploid cells and genetic variation by independent assortment and crossing over. HSW2, HSW5

(g)	the main stages of meiosis	To include interphase, prophase 1, metaphase 1, anaphase 1, telophase 1, prophase 2, metaphase 2, anaphase 2, telophase 2 (no details of the names of the stages within prophase 1 are required) and the term *homologous chromosomes*. **PAG1** HSW8
(h)	how cells of multicellular organisms are specialised for particular functions	To include erythrocytes, neutrophils, squamous and ciliated epithelial cells, sperm cells, palisade cells, root hair cells and guard cells. **PAG1**
(i)	the organisation of cells into tissues, organs and organ systems	To include squamous and ciliated epithelia, cartilage, muscle, xylem and phloem as examples of tissues.
(j)	the features and differentiation of stem cells	To include stem cells as a renewing source of undifferentiated cells.
(k)	the production of erythrocytes and neutrophils derived from stem cells in bone marrow	
(l)	the production of xylem vessels and phloem sieve tubes from meristems	
(m)	the potential uses of stem cells in research and medicine.	To include the repair of damaged tissues, the treatment of neurological conditions such as Alzheimer's and Parkinson's, and research into developmental biology. HSW2, HSW5, HSW6, HSW7, HSW9, HSW10, HSW11, HSW12

Module 3: Exchange and transport

In this module, learners study the structure and function of gas exchange and transport systems in a range of animals and in terrestrial plants.

The significance of surface area to volume ratio in determining the need for ventilation, gas exchange and transport systems in multicellular organisms is emphasised. The examples of terrestrial green plants and a range of animal phyla are used to illustrate the principle.

Learners are expected to apply knowledge, understanding and other skills developed in this module to new situations and/or to solve related problems.

2

3.1 Exchange and transport

3.1.1 Exchange surfaces

As animals become larger and more active, ventilation and gas exchange systems become essential to supply oxygen to, and remove carbon dioxide from, their bodies.

Ventilation and gas exchange systems in mammals, bony fish and insects are used as examples of the properties and functions of exchange surfaces in animals.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the need for specialised exchange surfaces	To include surface area to volume ratio (SA:V), metabolic activity, single-celled and multicellular organisms. *M0.1, M0.3, M0.4, M1.1, M2.1, M4.1* HSW1, HSW3, HSW5, HSW8
(b)	the features of an efficient exchange surface	To include, • increased surface area – root hair cells • thin layer – alveoli • good blood supply/ventilation to maintain gradient – gills/alveolus.
(c)	the structures and functions of the components of the mammalian gaseous exchange system	To include the distribution and functions of cartilage, ciliated epithelium, goblet cells, smooth muscle and elastic fibres in the trachea, bronchi, bronchioles and alveoli. **PAG1** HSW8
(d)	the mechanism of ventilation in mammals	To include the function of the rib cage, intercostal muscles (internal and external) and diaphragm. HSW8

(e)	the relationship between vital capacity, tidal volume, breathing rate and oxygen uptake	To include analysis and interpretation of primary and secondary data e.g. from a data logger or spirometer. *M0.1, M0.2, M0.4, M1.3* **PAG10** HSW2, HSW3, HSW4, HSW5, HSW6
(f)	the mechanisms of ventilation and gas exchange in bony fish and insects	To include: • bony fish – changes in volume of the buccal cavity and the functions of the operculum, gill filaments and gill lamellae (gill plates); countercurrent flow • insects – spiracles, trachea, thoracic and abdominal movement to change body volume, exchange with tracheal fluid. HSW8
(g)	the dissection, examination and drawing of the gaseous exchange system of a bony fish and/or insect trachea	**PAG2** HSW4
(h)	the examination of microscope slides to show the histology of exchange surfaces.	**PAG1** HSW4

3.1.2 Transport in animals

As animals become larger and more active, transport systems become essential to supply nutrients to, and remove waste from, individual cells.

Controlling the supply of nutrients and removal of waste requires the coordinated activity of the heart and circulatory system.

	Learning outcomes	**Additional guidance**
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the need for transport systems in multicellular animals	To include an appreciation of size, metabolic rate and surface area to volume ratio (SA:V). *M0.1, M0.3, M0.4, M1.1, M2.1, M4.1* HSW1, HSW3, HSW5, HSW8
(b)	the different types of circulatory systems	To include single, double, open and closed circulatory systems in insects, fish and mammals.
(c)	the structure and functions of arteries, arterioles, capillaries, venules and veins	To include the distribution of different tissues within the vessel walls. **PAG2**

(d)	the formation of tissue fluid from plasma	To include reference to hydrostatic pressure, oncotic pressure and an explanation of the differences in the composition of blood, tissue fluid and lymph. HSW8
(e)	**(i)** the external and internal structure of the mammalian heart **(ii)** the dissection, examination and drawing of the external and internal structure of the mammalian heart	**PAG2** HSW4
(f)	the cardiac cycle	To include the role of the valves and the pressure changes occurring in the heart and associated vessels. HSW2, HSW5, HSW8
(g)	how heart action is initiated and coordinated	To include the roles of the sino-atrial node (SAN), atrio-ventricular node (AVN), purkyne tissue and the myogenic nature of cardiac muscle (no detail of hormonal and nervous control is required at AS level). HSW2, HSW5, HSW8
(h)	the use and interpretation of electrocardiogram (ECG) traces	To include normal and abnormal heart activity e.g. tachycardia, bradycardia, fibrillation and ectopic heartbeat. *M0.1, M1.1, M1.3, M2.4* HSW2, HSW5
(i)	the role of haemoglobin in transporting oxygen and carbon dioxide	To include the reversible binding of oxygen molecules, carbonic anhydrase, haemoglobinic acid, HCO_3^- and the chloride shift. HSW8
(j)	the oxygen dissociation curve for fetal and adult human haemoglobin.	To include the significance of the different affinities for oxygen **AND** the changes to the dissociation curve at different carbon dioxide concentrations (the Bohr effect). *M3.1* HSW2, HSW8

3.1.3 Transport in plants

As plants become larger and more complex, transport systems become essential to supply nutrients to, and remove waste from, individual cells.

The supply of nutrients from the soil relies upon the flow of water through a vascular system, as does the movement of the products of photosynthesis.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the need for transport systems in multicellular plants	To include an appreciation of size, metabolic rate and surface area to volume ratio (SA:V). *M0.1, M0.3, M0.4, M1.1, M2.1, M4.1* HSW1, HSW3, HSW5, HSW8
(b) **(i)**	the structure and function of the vascular system in the roots, stems and leaves of herbaceous dicotyledonous plants	To include xylem vessels, sieve tube elements and companion cells.
(ii)	the examination and drawing of stained sections of plant tissue to show the distribution of xylem and phloem	**PAG1** HSW4
(iii)	the dissection of stems, both longitudinally and transversely, and their examination to demonstrate the position and structure of xylem vessels	**PAG2** HSW4
(c) **(i)**	the process of transpiration and the environmental factors that affect transpiration rate	To include an appreciation that transpiration is a consequence of gaseous exchange.
(ii)	practical investigations to estimate transpiration rates	To include the use of a potometer. *M0.1, M0.2, M1.1, M1.2, M1.3, M1.6, M1.11, M3.1, M3.2, M3.3, M3.5, M3.6, M4.1* **PAG5, PAG11** HSW2, HSW3, HSW4, HSW5, HSW6, HSW8
(d)	the transport of water into the plant, through the plant and to the air surrounding the leaves	To include details of the pathways taken by water **AND** the mechanisms of movement, in terms of water potential, adhesion, cohesion and the transpiration stream. HSW2, HSW8
(e)	adaptations of plants to the availability of water in their environment	To include xerophytes (cacti and marram grass) and hydrophytes (water lilies). HSW2

(f)	the mechanism of translocation.	To include translocation as an energy-requiring process transporting assimilates, especially sucrose, in the phloem between sources (e.g. leaves) and sinks (e.g. roots, meristem) **AND** details of active loading at the source and removal at the sink. HSW2, HSW8

Module 4: Biodiversity, evolution and disease

In this module the learners study the biodiversity of organisms; how they are classified and the ways in which biodiversity can be measured. It serves as an introduction to ecology, emphasising practical techniques and an appreciation of the need to maintain biodiversity. The learners also gain an understanding of the variety of organisms that are pathogenic and the way in which plants and animals have evolved defences to deal with disease. The impact of the evolution of pathogens on the treatment of disease is also considered.

The relationships between organisms are studied, considering variation, evolution and phylogeny.

Learners are expected to apply knowledge, understanding and other skills developed in this module to new situations and/or to solve related problems.

4.1 Communicable diseases, disease prevention and the immune system

4.1.1 Communicable diseases, disease prevention and the immune system

Organisms are surrounded by pathogens and have evolved defences against them. Medical intervention can be used to support these natural defences.

The mammalian immune system is introduced.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the different types of pathogen that can cause communicable diseases in plants and animals	To include, • bacteria – tuberculosis (TB), bacterial meningitis, ring rot (potatoes, tomatoes) • virus – HIV/AIDS (human), influenza (animals), Tobacco Mosaic Virus (plants) • protoctista – malaria, potato/tomato late blight • fungi – black sigatoka (bananas), ring worm (cattle), athlete's foot (humans).

(b)	the means of transmission of animal and plant communicable pathogens	To include direct and indirect transmission, reference to vectors, spores and living conditions – e.g. climate, social factors (no detail of the symptoms of specific diseases is required). *M0.1, M0.2, M0.3, M1.1, M1.2, M1.3, M1.5, M1.7, M3.1, M3.2* HSW1, HSW2, HSW3, HSW5, HSW6, HSW7, HSW8, HSW11, HSW12
(c)	plant defences against pathogens	To include production of chemicals **AND** plant responses that limit the spread of the pathogen (e.g. callose deposition).
(d)	the primary non-specific defences against pathogens in animals	Non-specific defences to include skin, blood clotting, wound repair, inflammation, expulsive reflexes and mucous membranes (no detail of skin structure is required). HSW2, HSW8
(e)	**(i)** the structure and mode of action of phagocytes **(ii)** examination and drawing of cells observed in blood smears	To include neutrophils and antigen-presenting cells **AND** the roles of cytokines, opsonins, phagosomes and lysosomes. **PAG1** HSW4, HSW8
(f)	the structure, different roles and modes of action of B and T lymphocytes in the specific immune response	To include the significance of cell signalling (reference to interleukins), clonal selection and clonal expansion, plasma cells, T helper cells, T killer cells and T regulator cells. HSW8
(g)	the primary and secondary immune responses	To include T memory cells and B memory cells. *M1.3* HSW2
(h)	the structure and general functions of antibodies	To include the general structure of an antibody molecule.
(i)	an outline of the action of opsonins, agglutinins and anti-toxins	
(j)	the differences between active and passive immunity, and between natural and artificial immunity	To include examples of each type of immunity.
(k)	autoimmune diseases	To include an appreciation of the term *autoimmune disease* and a named example e.g. arthritis, lupus.

(l)	the principles of vaccination and the role of vaccination programmes in the prevention of epidemics	To include routine vaccinations **AND** reasons for changes to vaccines and vaccination programmes (including global issues). *M0.1, M0.2, M0.3, M1.1, M1.2, M1.3, M1.5, M1.7, M3.1, M3.2* HSW1, HSW2, HSW3, HSW5, HSW6, HSW7, HSW8, HSW9, HSW11, HSW12
(m)	possible sources of medicines	To include examples of microorganisms and plants (and so the need to maintain biodiversity) **AND** the potential for personalised medicines and synthetic biology. HSW7, HSW9, HSW11, HSW12
(n)	the benefits and risks of using antibiotics to manage bacterial infection.	To include the wide use of antibiotics following the discovery of penicillin in the mid-20th century **AND** the increase in bacterial resistance to antibiotics (examples to include *Clostridium difficile* and MRSA) and its implications. HSW2, HSW5, HSW9, HSW12

4.2 Biodiversity

4.2.1 Biodiversity

Biodiversity refers to the variety and complexity of life. It is an important indicator in the study of habitats.

Maintaining biodiversity is important for many reasons. Actions to maintain biodiversity must be taken at local, national and global levels.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how biodiversity may be considered at different levels	To include habitat biodiversity (e.g. sand dunes, woodland, meadows, streams), species biodiversity (species richness and species evenness) and genetic biodiversity (e.g. different breeds within a species).
(b)	**(i)** how sampling is used in measuring the biodiversity of a habitat and the importance of sampling **(ii)** practical investigations collecting random and non-random samples in the field	To include how sampling can be carried out i.e. random sampling and non-random sampling (e.g. opportunistic, stratified and systematic) and the importance of sampling the range of organisms in a habitat. *M0.2, M1.3, M1.5, M1.4, M1.6, M1.7, M1.9, M1.10, M3.2* **PAG3** HSW4, HSW5, HSW6
(c)	how to measure species richness and species evenness in a habitat	*M1.1, M1.5, M2.3, M2.4*
(d)	the use and interpretation of Simpson's Index of Diversity (*D*) to calculate the biodiversity of a habitat	To include the formula: $D = 1 - (\Sigma(n/N)^2)$ **AND** the interpretation of both high and low values of Simpson's Index of Diversity (*D*). *M1.1, M1.5, M2.3, M2.4* HSW5

(e) how genetic biodiversity may be assessed, including calculations

To include calculations of genetic diversity within isolated populations, for example the percentage of gene variants (alleles) in a genome.

$$\textit{proportion of polymorphic gene loci} = \frac{\textit{number of polymorphic gene loci}}{\textit{total number of loci}}$$

Suitable populations include zoos (captive breeding), rare breeds and pedigree animals.

M1.1, M1.5, M2.3, M2.4
HSW5

(f) the factors affecting biodiversity

To include human population growth, agriculture (monoculture) and climate change.

M1.3, M1.7, M3.1
HSW5, HSW10, HSW12

(g) the ecological, economic and aesthetic reasons for maintaining biodiversity

Ecological, including protecting keystone species (interdependence of organisms) and maintaining genetic resource

- economic, including reducing soil depletion (continuous monoculture)
- aesthetic, including protecting
- landscapes.

HSW12

(h) *in situ* and *ex situ* methods of maintaining biodiversity

- *In situ* conservation including marine conservation zones and wildlife reserves
- *ex situ* conservation including seed banks, botanic gardens and zoos.

HSW7, HSW9, HSW10, HSW12

(i) international and local conservation agreements made to protect species and habitats.

Historic and/or current agreements, including the Convention on International Trade in Endangered Species (CITES), the Rio Convention on Biological Diversity (CBD) and the Countryside Stewardship Scheme (CSS).

HSW11, HSW12

4.2.2 Classification and evolution

Evolution has generated a very wide variety of organisms. The fact that all organisms share a common ancestry allows them to be classified. Classification is an attempt to impose a hierarchy on the complex and dynamic variety of life on Earth.

Classification systems have changed and will continue to change as our knowledge of the biology of organisms develops.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the biological classification of species	To include the taxonomic hierarchy of kingdom, phylum, class, order, family, genus and species **AND** domain. HSW1, HSW5, HSW6, HSW7
(b)	the binomial system of naming species and the advantage of such a system	
(c)	**(i)** the features used to classify organisms into the five kingdoms: Prokaryotae, Protoctista, Fungi, Plantae, Animalia	To include the use of similarities in observable features in original classification.
	(ii) the evidence that has led to new classification systems, such as the three domains of life, which clarifies relationships	To include the more recent use of similarities in biological molecules and other genetic evidence **AND** details of the three domains and a comparison of the kingdom and domain classification systems. HSW1, HSW5, HSW6, HSW7, HSW11, HSW12
(d)	the relationship between classification and phylogeny	(covered in outline only at AS level) HSW5, HSW7
(e)	the evidence for the theory of evolution by natural selection	To include the contribution of Darwin and Wallace in formulating the theory of evolution by natural selection **AND** fossil, DNA (only genomic DNA at AS level) and molecular evidence. HSW1, HSW2, HSW5, HSW6, HSW7

(f)	the different types of variation	To include intraspecific and interspecific variation **AND** the differences between continuous and discontinuous variation, using examples of a range of characteristics found in plants, animals and microorganisms **AND** both genetic and environmental causes of variation. An opportunity to use standard deviation to measure the spread of a set of data **and/or** Student's *t*-test to compare means of data values of two populations **and/or** the Spearman's rank correlation coefficient to consider the relationship of the data. *M1.2, M1.3, M1.6, M1.7, M1.10* HSW4
(g)	the different types of adaptations of organisms to their environment	Anatomical, physiological and behavioural adaptations **AND** why organisms from different taxonomic groups may show similar anatomical features, including the marsupial mole and placental mole. HSW5
(h)	the mechanism by which natural selection can affect the characteristics of a population over time	To include an appreciation that genetic variation, selection pressure and reproductive success (or failure) results in an increased proportion of the population possessing the advantageous characteristic(s). *M0.3* HSW8
(i)	how evolution in some species has implications for human populations.	To include the evolution of pesticide resistance in insects and drug resistance in microorganisms. HSW8, HSW9, HSW12

Module 5: Communication, homeostasis and energy

It is important that organisms, both plants and animals are able to respond to stimuli. This is achieved by communication within the body, which may be chemical and/or electrical. Both systems are covered in detail in this module. Communication is also fundamental to homeostasis with control of temperature, blood sugar and blood water potential being studied as examples.

In this module, the biochemical pathways of photosynthesis and respiration are considered, with an emphasis on the formation and use of ATP as the source of energy for biochemical processes and synthesis of biological molecules.

Learners are expected to apply knowledge, understanding and other skills developed in this module to new situations and/or to solve related problems.

5.1 Communication and homeostasis

5.1.1 Communication and homeostasis

Organisms use both chemical and electrical systems to monitor and respond to any deviation from the body's steady state.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the need for communication systems in multicellular organisms	To include the need for animals and plants to respond to changes in the internal and external environment and to coordinate the activities of different organs.
(b)	the communication between cells by cell signalling	To include signalling between adjacent cells and signalling between distant cells.
(c)	the principles of homeostasis	To include the differences between receptors and effectors, and the differences between negative feedback and positive feedback. HSW8
(d)	the physiological and behavioural responses involved in temperature control in ectotherms and endotherms.	To include, • endotherms – peripheral temperature receptors, the role of the hypothalamus and effectors in skin and muscles; behavioural responses • ectotherms – behavioural responses. An opportunity to monitor physiological functions in ectotherms and/or endotherms. **PAG11** HSW2

5.1.2 Excretion as an example of homeostatic control

The kidneys, liver and lungs are all involved in the removal of toxic products of metabolism from the blood and therefore contribute to homeostasis. The kidneys play a major role in the control of the water potential of the blood.

The liver also metabolises some toxins that are ingested.

2

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the term *excretion* and its importance in maintaining metabolism and homeostasis	To include reference to the importance of removing metabolic wastes, including carbon dioxide and nitrogenous waste, from the body.
(b)	**(i)** the structure and functions of the mammalian liver **(ii)** the examination and drawing of stained sections to show the histology of liver tissue	To include the gross structure and histology of the liver **AND** the roles of the liver in storage of glycogen, detoxification and the formation of urea (the ornithine cycle covered in outline only). **PAG1** HSW4
(c)	**(i)** the structure, mechanisms of action and functions of the mammalian kidney **(ii)** the dissection, examination and drawing of the external and internal structure of the kidney **(iii)** the examination and drawing of stained sections to show the histology of nephrons	To include the gross structure and histology of the kidney including the detailed structure of a nephron and its associated blood vessels **AND** the processes of ultrafiltration, selective reabsorption and the production of urine. *M0.1, M0.3, M1.1, M1.3, M2.1, M3.1* **PAG1, PAG2** HSW4, HSW6, HSW8
(d)	the control of the water potential of the blood	To include the role of osmoreceptors in the hypothalamus, the posterior pituitary gland, ADH and its effect on the walls of the collecting ducts. HSW8
(e)	the effects of kidney failure and its potential treatments	To include the problems that arise from kidney failure including the effect on glomerular filtration rate (GFR) and electrolyte balance **AND** the use of renal dialysis and transplants for the treatment of kidney failure. HSW7, HSW9, HSW12

(f)	how excretory products can be used in medical diagnosis.	To include the use of urine samples in diagnostic tests, with reference to the use of monoclonal antibodies in pregnancy testing and testing for anabolic steroids and drugs. **PAG9** HSW7, HSW9, HSW11, HSW12

5.1.3 Neuronal communication

The stimulation of sensory receptors leads to the generation of an action potential in a neurone.

Transmission between neurones takes place at synapses.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the roles of mammalian sensory receptors in converting different types of stimuli into nerve impulses	To include an outline of the roles of sensory receptors (e.g. Pacinian corpuscle) in responding to specific types of stimuli and their roles as transducers.
(b)	the structure and functions of sensory, relay and motor neurones	To include differences between the structure and function of myelinated and non-myelinated neurones.
(c)	the generation and transmission of nerve impulses in mammals	To include how the resting potential is established and maintained and how an action potential is generated (including reference to positive feedback) and transmitted in a myelinated neurone **AND** the significance of the frequency of impulse transmission. *M1.3, M3.1*
(d)	the structure and roles of synapses in neurotransmission.	To include the structure of a cholinergic synapse **AND** the action of neurotransmitters at the synapse and the importance of synapses in summation and control.

5.1.4 Hormonal communication

The ways in which specific hormones bring about their effects are used to exemplify endocrine communication and control. Treatment of diabetes is used as an example of the use of medical technology in overcoming defects in hormonal control systems.

2

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	endocrine communication by hormones	To include secretion of hormones into the blood, transport by the blood, and detection by target cells or tissues.
(b)	the structure and functions of the adrenal glands	Adrenal glands as an example of endocrine glands, to include the hormones secreted by the cortex and medulla and their functions.
(c) **(i)**	the histology of the pancreas	To include the endocrine tissues.
(ii)	the examination and drawing of stained sections of the pancreas to show the histology of the endocrine tissues	**PAG1** HSW4
(d)	how blood glucose concentration is regulated	To include the action of insulin and glucagon as an example of negative feedback, and the role of the liver **AND** the control of insulin secretion, with reference to potassium channels and calcium channels in the beta cells of the pancreas. HSW12
(e)	the differences between Type 1 and Type 2 diabetes mellitus	To include the causes of Type 1 and Type 2 diabetes and the treatments used for each. HSW12
(f)	the potential treatments for diabetes mellitus.	To include the use of insulin produced by genetically modified bacteria and the potential use of stem cells to treat diabetes mellitus. HSW12

5.1.5 Plant and animal responses

Plant responses to environmental changes are coordinated by hormones, some of which are important commercially.

In animals, responding to changes in the environment is a complex and continuous process, involving nervous, hormonal and muscular coordination.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)** the types of plant responses **(ii)** practical investigations into phototropism and geotropism	To include the response to abiotic stress and herbivory e.g. chemical defences (such as tannins, alkaloids and pheromones), folding in response to touch (*Mimosa pudica*) **AND** the range of tropisms in plants. *M1.3, M1.6* **PAG11** HSW4
(b)	the roles of plant hormones	To include the role of hormones in leaf loss in deciduous plants, seed germination and stomatal closure.
(c)	the experimental evidence for the role of auxins in the control of apical dominance	HSW5
(d)	the experimental evidence for the role of gibberellin in the control of stem elongation and seed germination	HSW5
(e)	practical investigations into the effect of plant hormones on growth	An opportunity for serial dilution. An opportunity to use standard deviation to measure the spread of a set of data. *M0.2, M1.1, M1.2, M1.3, M1.4, M1.6, M1.9, M1.10, M3.1, M3.2* **PAG11** HSW4
(f)	the commercial use of plant hormones	To include the use of hormones to control ripening, the use of rooting powders and hormonal weed killers. HSW12
(g)	the organisation of the mammalian nervous system	To include the structural organisation of the nervous system into the central and peripheral systems **AND** the functional organisation into the somatic and autonomic nervous systems.

(h)	the structure of the human brain and the functions of its parts	To include the gross structure of the human brain **AND** the functions of the cerebrum, cerebellum, medulla oblongata, hypothalamus and pituitary gland.
(i)	reflex actions	To include knee jerk reflex and blinking reflex, with reference to the survival value of reflex actions. *M0.1, M0.2, M1.1, M1.2, M1.3, M1.6* **PAG11** HSW4
(j)	the coordination of responses by the nervous and endocrine systems	To include the 'fight or flight' response to environmental stimuli in mammals **AND** the action of hormones in cell signalling (studied in outline only) with reference to adrenaline (first messenger), activation of adenylyl cyclase, and cyclic AMP (second messenger).
(k)	the effects of hormones and nervous mechanisms on heart rate	An opportunity to monitor physiological functions, for example with pulse rate measurements before, during and after exercise or sensors to record electrical activity in the heart. An opportunity to use standard deviation to measure the spread of a set of data and/or Student's *t*-test to compare means of data values of two sets of data. *M0.1, M0.2, M0.3, M1.1, M1.2, M1.3, M1.6, M1.10, M3.1* **PAG10, PAG11**
(l) **(i)**	the structure of mammalian muscle and the mechanism of muscular contraction	To include the structural and functional differences between skeletal, involuntary and cardiac muscle **AND** the action of neuromuscular junctions **AND** the sliding filament model of muscular contraction and the role of ATP, and how the supply of ATP is maintained in muscles by creatine phosphate. An opportunity to monitor muscle contraction and fatigue using sensors to record electrical activity. **PAG1, PAG10, PAG11** HSW4
(ii)	the examination of stained sections or photomicrographs of skeletal muscle.	

5.2 Energy for biological processes

5.2.1 Photosynthesis

Photosynthesis is the process whereby light from the Sun is harvested and used to drive the production of chemicals, including ATP, and used to synthesise large organic molecules from inorganic molecules.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the interrelationship between the process of photosynthesis and respiration	To include the relationship between the raw materials and products of the two processes. *M0.1, M0.3, M0.4, M3.4*
(b)	the structure of a chloroplast and the sites of the two main stages of photosynthesis	The components of a chloroplast including outer membrane, lamellae, grana, thylakoid, stroma and DNA.
(c)	**(i)** the importance of photosynthetic pigments in photosynthesis	To include reference to light harvesting systems and photosystems.
	(ii) practical investigations using thin layer chromatography (TLC) to separate photosynthetic pigments	*M0.1, M0.2, M1.1, M1.3, M2.2, M2.3, M2.4* **PAG6** HSW4
(d)	the light-dependent stage of photosynthesis	To include how energy from light is harvested and used to drive the production of chemicals which can be used as a source of energy for other metabolic processes (ATP and reduced NADP) with reference to electron carriers and cyclic and non-cyclic photophosphorylation **AND** the role of water. HSW8
(e)	the fixation of carbon dioxide and the light-independent stage of photosynthesis	To include how the products of the light-dependent stage are used in the light-independent stage (Calvin cycle) to produce triose phosphate (TP) with reference to ribulose bisphosphate (RuBP), ribulose bisphosphate carboxylase (RuBisCO) and glycerate 3-phosphate (GP) – **no** other biochemical detail is required. HSW8
(f)	the uses of triose phosphate (TP)	To include the use of TP as a starting material for the synthesis of carbohydrates, lipids and amino acids **AND** the recycling of TP to regenerate the supply of RuBP.

(g)	**(i)**	factors affecting photosynthesis	To include limiting factors in photosynthesis with reference to carbon dioxide concentration, light intensity and temperature, and the implications of water stress (stomatal closure) **AND** the effect on the rate of photosynthesis, and on levels of GP, RuBP and TP, of changing carbon dioxide concentration, light intensity and temperature.
	(ii)	practical investigations into factors affecting the rate of photosynthesis.	An opportunity to use sensors, data loggers and software to process data. *M0.1, M0.2, M0.3, M1.1, M1.3, M1.11, M3.1, M3.2, M3.4, M3.5, M3.6, M4.1* **PAG4, PAG10, PAG11** HSW3, HSW4, HSW5, HSW12

5.2.2 Respiration

Respiration is the process whereby energy stored in complex organic molecules is transferred to ATP. ATP provides the immediate source of energy for biological processes.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the need for cellular respiration	To include examples of why plants, animals and microorganisms need to respire (suitable examples could include active transport and an outline of named metabolic reactions).
(b)	the structure of the mitochondrion	The components of a mitochondrion including inner and outer michondrial membranes, cristae, matrix and mitochondrial DNA.
(c)	the process and site of glycolysis	To include the phosphorylation of glucose to hexose bisphosphate, the splitting of hexose bisphosphate into two triose phosphate molecules and further oxidation to pyruvate **AND** the production of a small yield of ATP and reduced NAD. HSW8
(d)	the link reaction and its site in the cell	To include the decarboxylation of pyruvate to acetate, the reduction of NAD, and the combination of acetate with coenzyme A.

(e)	the process and site of the Krebs cycle	To include the formation of citrate from acetate and oxaloacetate and the reconversion of citrate to oxaloacetate (names of intermediate compounds are not required) **AND** the importance of decarboxylation, dehydrogenation, the reduction of NAD and FAD, and substrate level phosphorylation. HSW8
(f)	the importance of coenzymes in cellular respiration	With reference to NAD, FAD and coenzyme A.
(g)	the process and site of oxidative phosphorylation	To include the roles of electron carriers, oxygen and the mitochondrial cristae.
(h)	the chemiosmotic theory	To include the electron transport chain, proton gradients and ATP synthase in oxidative phosphorylation and photophosphorylation.
(i)	**(i)** the process of anaerobic respiration in eukaryotes **(ii)** practical investigations into respiration rates in yeast, under aerobic and anaerobic conditions	To include anaerobic respiration in mammals and yeast and the benefits of being able to respire anaerobically **AND** why anaerobic respiration produces a much lower yield of ATP than aerobic respiration. An opportunity to use sensors, data loggers and software to process data. *M0.1, M0.2, M1.1, M1.3, M2.4, M3.1, M3.2* **PAG4, PAG10, PAG11** HSW3, HSW4
(j)	the difference in relative energy values of carbohydrates, lipids and proteins as respiratory substrates	
(k)	the use and interpretation of the respiratory quotient (RQ)	To include calculating the respiratory quotient (RQ) using the formula: $RQ = \frac{CO_2 \text{ produced}}{O_2 \text{ consumed}}$ *M0.1, M0.2, M1.1, M1.3, M2.3*

(l)	practical investigations into the effect of factors such as temperature, substrate concentration and different respiratory substrates on the rate of respiration.	For example the use of respirometers. An opportunity to use sensors, data loggers and software to process data. An opportunity to use standard deviation to measure the spread of a set of data and/or Student's *t*-test to compare means of data values of two sets of data. *M0.1, M0.2, M1.1, M1.2, M1.3, M1.6, M1.10, M2.4, M3.2, M3.3, M3.5, M3.6* **PAG4, PAG10, PAG11** HSW3, HSW4

Module 6: Genetics, evolution and ecosystems

This module covers the role of genes in regulating and controlling cell function and development. Heredity and the mechanisms of evolution and speciation are also covered.

Some of the practical techniques used to manipulate DNA such as sequencing and amplification are considered and their therapeutic medical use. The use of microorganisms in biotechnology is also covered. Both of these have associated ethical considerations and it is important that learners develop a balanced understanding of such issues.

Learners gain an appreciation of the role of microorganisms in recycling materials within the environment and maintaining balance within ecosystems. The need to conserve environmental resources in a sustainable fashion is considered, whilst appreciating the potential conflict arising from the needs of an increasing human population. Learners also consider the impacts of human activities on the natural environment and biodiversity.

Learners are expected to apply knowledge, understanding and other skills developed in this module to new situations and/or to solve related problems.

6.1 Genetics and evolution

6.1.1 Cellular control

The way in which cells control metabolic reactions determines how organisms, grow, develop and function.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	types of gene mutations and their possible effects on protein production and function	To include substitution, insertion or deletion of one or more nucleotides **AND** the possible effects of these gene mutations (i.e. beneficial, neutral or harmful).

(b)	the regulatory mechanisms that control gene expression at the transcriptional level, post-transcriptional level and post-translational level	To include control at the, • transcriptional level: *lac* operon, and transcription factors in eukaryotes. • post-transcriptional level: the editing of primary mRNA and the removal of introns to produce mature mRNA. • post-translational level: the activation of proteins by cyclic AMP. HSW2
(c)	the genetic control of the development of body plans in different organisms	Homeobox gene sequences in plants, animals and fungi are similar and highly conserved **AND** the role of Hox genes in controlling body plan development. HSW7
(d)	the importance of mitosis and apoptosis as mechanisms controlling the development of body form.	To include an appreciation that the genes which regulate the cell cycle and apoptosis are able to respond to internal and external cell stimuli e.g. stress.

6.1.2 Patterns of inheritance

Isolating mechanisms can lead to the accumulation of different genetic information in populations, potentially leading to new species. Over a prolonged period of time, organisms have changed and some have become extinct. The theory of evolution explains these changes. Humans use artificial selection to produce similar changes in plants and animals.

		Learning outcomes	Additional guidance
		Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)**	the contribution of both environmental and genetic factors to phenotypic variation	To include examples of both genetic and environmental contributions – environmental examples could include diet in animals and etiolation or chlorosis in plants.
	(ii)	how sexual reproduction can lead to genetic variation within a species	Meiosis and the random fusion of gametes at fertilisation.
(b)	**(i)**	genetic diagrams to show patterns of inheritance	To include monogenic inheritance, dihybrid inheritance, multiple alleles, sex linkage and codominance.
	(ii)	the use of phenotypic ratios to identify linkage (autosomal and sex linkage) and epistasis	To include explanations of linkage and epistasis. *M0.3, M1.4* HSW2, HSW8

(c)	using the chi-squared (χ^2) test to determine the significance of the difference between observed and expected results	The formula for the chi-squared (χ^2) test will be provided. *M0.3, M1.4, M1.9, M2.1*
(d)	the genetic basis of continuous and discontinuous variation	To include reference to the number of genes that influence each type of variation.
(e)	the factors that can affect the evolution of a species	To include stabilising selection and directional selection, genetic drift, genetic bottleneck and founder effect.
(f)	the use of the Hardy–Weinberg principle to calculate allele frequencies in populations	The equations for the Hardy–Weinberg principle will be provided. *M0.2, M2.1, M2.2, M2.3*
(g)	the role of isolating mechanisms in the evolution of new species	To include geographical mechanisms (allopatric speciation) and reproductive mechanisms (sympatric speciation).
(h) **(i)**	the principles of artificial selection and its uses	To include examples of selective breeding in plants and animals **AND** an appreciation of the importance of maintaining a resource of genetic material for use in selective breeding including wild types.
(ii)	the ethical considerations surrounding the use of artificial selection.	To include a consideration of the more extreme examples of the use of artificial selection to 'improve' domestic species e.g. dog breeds. HSW2, HSW8, HSW10, HSW12

6.1.3 Manipulating genomes

Genome sequencing gives information about the location of genes and provides evidence for the evolutionary links between organisms.

Genetic engineering involves the manipulation of naturally occurring processes and enzymes. The capacity to manipulate genes has many potential benefits, but the implications of genetic techniques are subject to much public debate

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the principles of DNA sequencing and the development of new DNA sequencing techniques	To include the rapid advancements of the techniques used in sequencing, which have increased the speed of sequencing and allowed whole genome sequencing e.g. high-throughput sequencing. HSW7
(b)	**(i)** how gene sequencing has allowed for genome-wide comparisons between individuals and between species **(ii)** how gene sequencing has allowed for the sequences of amino acids in polypeptides to be predicted **(iii)** how gene sequencing has allowed for the development of synthetic biology	With reference to bioinformatics and computational biology and how these fields are contributing to biological research into genotype–phenotype relationships, epidemiology and searching for evolutionary relationships. **PAG10** HSW7, HSW9
(c)	the principles of DNA profiling and its uses	To include forensics and analysis of disease risk. HSW9
(d)	the principles of the polymerase chain reaction (PCR) and its application in DNA analysis	
(e)	the principles and uses of electrophoresis for separating nucleic acid fragments or proteins	Opportunity for practical use of electrophoresis. **PAG6** HSW4
(f)	**(i)** the principles of genetic engineering	To include the isolation of genes from one organism and the placing of these genes into another organism using suitable vectors.
	(ii) the techniques used in genetic engineering	To include the use of restriction enzymes, plasmids and DNA ligase to form recombinant DNA with the desired gene and electroporation. HSW2

(g)	the ethical issues (both positive and negative) relating to the genetic manipulation of animals (including humans), plants and microorganisms	To include insect resistance in genetically modified soya, genetically modified pathogens for research and 'pharming' i.e. genetically modified animals to produce pharmaceuticals **AND** issues relating to patenting and technology transfer e.g. making genetically modified seed available to poor farmers. HSW10
(h)	the principles of, and potential for, gene therapy in medicine.	To include the differences between somatic cell gene therapy and germ line cell gene therapy. HSW9, HSW12

6.2 Cloning and biotechnology

6.2.1 Cloning and biotechnology

Farmers and growers exploit "natural" vegetative propagation in the production of uniform crops. Artificial clones of plants and animals can now be produced.

Biotechnology is the industrial use of living organisms (or parts of living organisms) to produce food, drugs or other product.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)** natural clones in plants and the production of natural clones for use in horticulture **(ii)** how to take plant cuttings as an example of a simple cloning technique	To include examples of natural cloning and the methods used to produce clone (various forms of vegetative propagation). Dissection of a selection of plant material to produce cuttings. **PAG2** HSW4
(b)	**(i)** the production of artificial clones of plants by micropropagation and tissue culture **(ii)** the arguments for and against artificial cloning in plants	To include an evaluation of the uses of plant cloning in horticulture and agriculture. HSW9, HSW12
(c)	natural clones in animal species	To include examples of natural clones (twins formed by embryo splitting).
(d)	**(i)** how artificial clones in animals can be produced by artificial embryo twinning or by enucleation and somatic cell nuclear transfer (SCNT) **(ii)** the arguments for and against artificial cloning in animals	To include an evaluation of the uses of animal cloning (examples including in agriculture and medicine, and issues of longevity of cloned animals). HSW9, HSW10, HSW12

(e)	the use of microorganisms in biotechnological processes	To include reasons why microorganisms are used e.g. economic considerations, short life cycle, growth requirements **AND** processes including brewing, baking, cheese making, yoghurt production, penicillin production, insulin production and bioremediation.
(f)	the advantages and disadvantages of using microorganisms to make food for human consumption	To include bacterial and fungal sources. HSW9, HSW12
(g)	**(i)** how to culture microorganisms effectively, using aseptic techniques	An opportunity for serial dilutions and culturing on agar plates. **PAG7** HSW4
	(ii) the importance of manipulating the growing conditions in batch and continuous fermentation in order to maximise the yield of product required	
(h)	**(i)** the standard growth curve of a microorganism in a closed culture	
	(ii) practical investigations into the factors affecting the growth of microorganisms	An opportunity for serial dilutions and the use of broth. *M0.1, M0.3, M0.5, M1.1, M1.3, M2.5, M3.1, M3.2, M3.4, M3.5, M3.6* **PAG7** HSW4

(i)	the uses of immobilised enzymes in biotechnology and the different methods of immobilisation.	To include methods of enzyme immobilisation **AND** an evaluation of the use of immobilised enzymes in biotechnology examples could include: • glucose isomerase for the conversion of glucose to fructose • penicillin acyclase for the formation of semi-synthetic penicillins (to which some penicillin-resistant organisms are not resistant) • lactase for the hydrolysis of lactose to glucose and galactose • aminoacyclase for production of pure samples of L-amino acids • glucoamylase for the conversion of dextrins to glucose • nitrilase for the conversion of acrylonitrile to acrylamide (for use in the plastics industry). *M0.2, M0.3, M1.2, M1.3, M1.4, M1.6, M1.10, M3.2, M4.1* **PAG4** HSW4

6.3 Ecosystems

6.3.1 Ecosystems

Organisms do not live in isolation but engage in complex interactions, not just with other organisms but also with their environment.

The efficiency of biomass transfer limits the number of organisms that can exist in a particular ecosystem.

Ecosystems are dynamic and tend towards some form of climax community.

	Learning outcomes	**Additional guidance**
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	ecosystems, which range in size, are dynamic and are influenced by both biotic and abiotic factors	To include reference to a variety of ecosystems of different sizes (e.g. a rock pool, a playing field, a large tree) and named examples of biotic and abiotic factors.

(b)	biomass transfers through ecosystems	To include how biomass transfers between trophic levels can be measured **AND** the efficiency of biomass transfers between trophic levels **AND** how human activities can manipulate the transfer of biomass through ecosystems. *M0.1, M0.2, M0.3, M0.4, M1.1, M1.3, M1.6* HSW12
(c)	recycling within ecosystems	To include the role of decomposers and the roles of microorganisms in recycling nitrogen within ecosystems (including *Nitrosomonas*, *Nitrobacter*, *Azotobacter* and *Rhizobium*) **AND** the importance of the carbon cycle to include the role of organisms (decomposition, respiration and photosynthesis) and physical and chemical effects in the cycling of carbon within ecosystems. HSW2, HSW12
(d)	the process of primary succession in the development of an ecosystem	To include succession from pioneer species to a climax community **AND** deflected succession. HSW12
(e)	**(i)** how the distribution and abundance of organisms in an ecosystem can be measured **(ii)** the use of sampling and recording methods to determine the distribution and abundance of organisms in a variety of ecosystems.	M*1.3, M1.4, M1.5, M1.7, M1.9, M1.10, M3.1, M3.2* **PAG3** HSW4

6.3.2 Populations and sustainability

There are many factors that determine the size of a population.

For economic, social and ethical reasons ecosystems may need to be carefully managed.

To support an increasing human population, we need to use biological resources in a sustainable way.

2

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the factors that determine size of a population	To include the significance of limiting factors in determining the carrying capacity of a given environment and the impact of these factors on final population size. *M0.1, M0.2, M0.3, M0.4, M0.5, M1.3, M2.5, M3.1, M3.2* HSW1, HSW2
(b)	interactions between populations	To include predator–prey relationships considering the effects on both predator and prey populations **AND** interspecific and intraspecific competition.
(c)	the reasons for, and differences between, conservation and preservation	To include the economic, social and ethical reasons for conservation of biological resources. HSW7, HSW9, HSW10, HSW12
(d)	how the management of an ecosystem can provide resources in a sustainable way	Examples to include timber production and fishing. HSW12
(e)	the management of environmental resources and the effects of human activities.	To include how ecosystems can be managed to balance the conflict between conservation/ preservation and human needs e.g. the Masai Mara region in Kenya and the Terai region of Nepal, peat bogs **AND** the effects of human activities on the animal and plant populations and how these are controlled in environmentally sensitive ecosystems e.g. the Galapagos Islands, Antarctica, Snowdonia National Park, the Lake District. HSW7, HSW12

2d. Prior knowledge, learning and progression

This specification has been developed for learners who wish to continue with a study of biology at Level 3. The A level specification has been written to provide progression from GCSE Science, GCSE Additional Science, GCSE Further Additional Science, GCSE Biology or from AS Level Biology achievement at a minimum of grade C (or equivalent) in these qualifications should be seen as the normal requisite for entry to A Level Biology A. However, learners who have successfully taken other Level 2 qualifications in Science or Applied Science with appropriate biology content may also have acquired sufficient knowledge and understanding to begin the A Level Biology course.

There is no formal requirement for prior knowledge of biology for entry onto this qualification. Other learners without formal qualifications may have acquired sufficient knowledge of biology to enable progression onto the course.

Some learners may wish to follow a biology course for only one year as an AS, in order to broaden their curriculum, and to develop their interest and understanding of different areas of the subject. Others may follow a co-teachable route, completing the one year AS course and/or then moving to the two-year A level. The A Level Biology A course will prepare learners for progression to undergraduate study, enabling them to enter a range of academic and vocational careers in biological sciences, medicine and biomedical sciences, veterinary science, agriculture and related sectors. For learners wishing to follow an apprenticeship route or those seeking direct entry into biological science careers, this A level provides a strong background and progression pathway.

There are a number of Science specifications at OCR. Find out more at **www.ocr.org.uk**.

3 Assessment of OCR A Level in Biology A

3a. Forms of assessment

All three externally assessed components (01–03) contain some synoptic assessment, some extended response questions and some stretch and challenge questions.

Stretch and challenge questions are designed to allow the most able learners the opportunity to demonstrate the full extent of their knowledge and skills.

Stretch and challenge questions will support the awarding of A* grade at A level, addressing the need for greater differentiation between the most able learners.

Biological processes (Component 01)

This component is worth 100 marks, is split into two sections and assesses content from teaching modules 1, 2, 3 and 5. Learners answer all the questions.

Section A contains multiple choice questions. This section of the paper is worth 15 marks.

Section B includes short answer question styles (structured questions, problem solving, calculations, practical) and extended response questions. This section of the paper is worth 85 marks.

Biological diversity (Component 02)

This component is worth 100 marks, is split into two sections and assesses content from teaching modules 1, 2, 4 and 6. Learners answer all the questions.

Section A contains multiple choice questions. This section of the paper is worth 15 marks.

Section B includes short answer question styles (structured questions, problem solving, calculations, practical) and extended response questions. This section of the paper is worth 85 marks.

Unified biology (Component 03)

This component assesses content from across all teaching modules 1 to 6. Learners answer all the questions. This component is worth 70 marks.

Question styles include short answer (structured questions, problem solving, calculations, practical) and extended response questions.

Practical endorsement in biology (Component 04)

Performance in this component is reported separately to the performance in the A level as measured through externally assessed components 01 to 03. This non-exam assessment component rewards the development of practical competency for biology and is teacher assessed. Learners complete a minimum of 12 assessed experiments covering the technical skills (together with the use of apparatus and practical techniques) specified in Section 5g.

Learners may work in groups but must be able to demonstrate and record independent evidence of their competency. Teachers who award a pass to their learners need to be confident that the learner consistently and routinely exhibits the competencies listed in Section 5g before completion of the A level course.

Full details still to be confirmed with Ofqual.

3b. Assessment objectives (AO)

There are three assessment objectives in OCR's A Level in Biology A. These are detailed in the table below.

Learners are expected to demonstrate their ability to:

	Assessment Objective
AO1	Demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures.
AO2	Apply knowledge and understanding of scientific ideas, processes, techniques and procedures: • in a theoretical context • in a practical context • when handling qualitative data • when handling quantitative data.
AO3	Analyse, interpret and evaluate scientific information, ideas and evidence, including in relation to issues, to: • make judgements and reach conclusions • develop and refine practical design and procedures.

AO weightings in A Level in Biology A

The relationship between the assessment objectives and the components are shown in the following table:

Component	% of A Level in Biology A (H420)		
	AO1	AO2	AO3
Biological processes (H420/01)	13–14	15–16	8–9
Biological diversity (H420/02)	13–14	15–16	8–9
Unified biology (H420/03)	5–6	10–11	9–10
Practical endorsement in biology (H420/04)*	N/A	N/A	N/A
Total	**31–34**	**40–43**	**25–28**

* The Practical Endorsement is assessed and reported separately from the overall A level grade (see Section 5g).

3c. Assessment availability

There will be one examination series available each year in May/June to **all** learners.

All examined components must be taken in the same examination series at the end of the course.

This specification will be certificated from the June 2017 examination series onwards.

3d. Retaking the qualification

Learners can retake the qualification as many times as they wish. They retake all examined components of the qualification.

3e. Assessment of extended responses

The assessment materials for this qualification provide learners with the opportunity to demonstrate their ability to construct and develop a sustained and coherent line of reasoning and marks for extended responses are integrated into the marking criteria.

3f. Synoptic assessment

Synoptic assessment tests the learners' understanding of the connections between different elements of the subject.

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the A level course. The emphasis of synoptic assessment is to encourage the development of the understanding of the subject as a discipline. All components within Biology A contain an element of synoptic assessment.

Synoptic assessment requires learners to make and use connections within and between different areas of biology, for example, by:

- applying knowledge and understanding of more than one area to a particular situation or context
- using knowledge and understanding of principles and concepts in planning experimental and investigative work and in the analysis and evaluation of data
- bringing together scientific knowledge and understanding from different areas of the subject and applying them.

3g. Calculating qualification results

A learner's overall qualification grade for A Level in Biology A will be calculated by adding together their marks from the three examined components taken to give their total weighted mark.

This mark will then be compared to the qualification level grade boundaries for the entry option taken by the learner and for the relevant exam series to determine the learner's overall qualification grade.

A learner's result for their Practical endorsement in Biology component will not contribute to their overall qualification grade.

4 Admin: what you need to know

The information in this section is designed to give an overview of the processes involved in administering this qualification so that you can speak to your exams officer. All of the following processes require you to submit something to OCR by a specific deadline. More information about these processes, together with the deadlines, can be found in the *OCR Admin Guide and Entry Codes: 14–19 Qualifications*, which can be downloaded from the OCR website: **www.ocr.org.uk**

4a. Pre-assessment

Estimated entries

Estimated entries are your best projection of the number of learners who will be entered for a qualification in a particular series. Estimated entries should be submitted to OCR by the specified deadline. They are free and do not commit your centre in any way.

Final entries

Final entries provide OCR with detailed data for each learner, showing each assessment to be taken. It is essential that you use the correct entry code, considering the relevant entry rules.

Final entries must be submitted to OCR by the published deadlines or late entry fees will apply.

All learners taking A Level in Biology A must be entered using the entry code H420.

Entry option		Components		
Entry code	**Title**	**Code**	**Title**	**Assessment type**
H420	Biology A	01	Biological processes	External assessment
		02	Biological diversity	External assessment
		03	Unified biology	External assessment
		04	* Practical endorsement in biology	Non exam assessment (Visiting moderation)

* Details to be confirmed by Ofqual.

Estimated grades

An estimated grade is the grade the centre expects a learner to achieve for a qualification. These should be submitted to OCR by the specified deadline.

4b. Accessibility and special consideration

Reasonable adjustments and access arrangements allow learners with special educational needs, disabilities or temporary injuries to access the assessment and show what they know and can do, without changing the demands of the assessment.

Applications for these should be made before the examination series. Detailed information about eligibility for access arrangements can be found in the JCQ *Access Arrangements and Reasonable Adjustments*.

Special consideration is a post-assessment adjustment to marks or grades to reflect temporary injury, illness or other indisposition at the time the assessment was taken. Detailed information about eligibility for special consideration can be found in the JCQ *A guide to the special consideration process*.

4c. External assessment arrangements

Regulations governing examination arrangements are contained in the JCQ *Instructions for conducting examinations*

4d. Non exam assessment

Details to be confirmed by Ofqual. See Section 5g.

4e. Results and certificates

Grade scale

A level qualifications are graded on the scale: A*, A, B, C, D, E, where A* is the highest. Learners who fail to reach the minimum standard for E will be Unclassified (U). Only subjects in which grades A* to E are attained will be recorded on certificates.

The Practical endorsement in biology will be graded: Pass or Fail. Learners who do not reach the minimum standard of Pass will receive a Fail. Where a grade of Pass is attained this will be recorded on the certificate alongside the learner's qualification grade.

Results

Results are released to centres and learners for information and to allow any queries to be resolved **before** certificates are issued.

Centres will have access to the following results information for each learner:

- the grade for the qualification
- the raw mark for each component
- the total weighted mark for the qualification.

The following supporting information will be available:

- raw mark grade boundaries for each component
- weighted mark grade boundaries for each entry option.

Until certificates are issued, results are deemed to be provisional and may be subject to amendment. A learner's final results will be recorded on an OCR certificate.

The qualification title will be shown on the certificate as 'OCR Level 3 Advanced GCE in Biology A'.

4f. Post-results services

A number of post-results services are available:

- **Enquiries about results** – If you are not happy with the outcome of a learner's results, centres may submit an enquiry about results.
- **Missing and incomplete results** – This service should be used if an individual subject result for a learner is missing, or the learner has been omitted entirely from the results supplied.
- **Access to scripts** – Centres can request access to marked scripts.

4g. Malpractice

Any breach of the regulations for the conduct of examinations and non-examination assessment work may constitute malpractice (which includes maladministration) and must be reported to OCR as soon as it is detected.

Detailed information on malpractice can be found in the *Suspected Malpractice in Examinations and Assessments: Policies and Procedures* published by JCQ.

5 Appendices

5a. Grade descriptors

Details to be confirmed by Ofqual.

5b. Overlap with other qualifications

There is a small degree of overlap between the content of this specification and those for A Level Chemistry, Physics, Science, Geography and Geology courses. The links between the specifications may allow for some co-teaching, particularly in the areas of biochemistry, environmental science and microbiology.

5c. Avoidance of bias

The A level qualification and subject criteria have been reviewed in order to identify any feature which could disadvantage learners who share a protected characteristic as defined by the Equality Act 2010. All reasonable steps have been taken to minimise any such disadvantage.

5d. How Science Works (HSW)

How Science Works (HSW) was conceived as being a wider view of science in context, rather than just straightforward scientific enquiry. It was intended to develop learners as critical and creative thinkers, able to solve problems in a variety of contexts.

Developing ideas and theories to explain the operation of living systems, from the molecular to the ecosystem level, is at the heart of Biology. Learners should be aware of the importance that peer review and repeatability have in giving confidence to this evidence.

Learners are expected to understand the variety of sources of data available for critical analysis to provide evidence and the uncertainty involved in its measurement. They should also be able to link that evidence to contexts influenced by culture, politics and ethics.

Understanding *How Science Works* requires an understanding of how scientific evidence can influence ideas and decisions for individuals and society, which is linked to the necessary skills of communication for audience and for purpose with appropriate scientific terminology.

The examples and guidance within the specification are not exhaustive but give a flavour of opportunities for integrating HSW within the course. These references, written in the form HSW1, link to the statements as detailed below:

- **HSW1** Use theories, models and ideas to develop scientific explanations
- **HSW2** Use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas
- **HSW3** Use appropriate methodology, including information and communication technology (ICT), to answer scientific questions and solve scientific problems
- **HSW4** Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts
- **HSW5** Analyse and interpret data to provide evidence, recognising correlations and causal relationships
- **HSW6** Evaluate methodology, evidence and data, and resolve conflicting evidence
- **HSW7** Know that scientific knowledge and understanding develops over time
- **HSW8** Communicate information and ideas in appropriate ways using appropriate terminology
- **HSW9** Consider applications and implications of science and evaluate their associated benefits and risks
- **HSW10** Consider ethical issues in the treatment of humans, other organisms and the environment
- **HSW11** Evaluate the role of the scientific community in validating new knowledge and ensuring integrity
- **HSW12** Evaluate the ways in which society uses science to inform decision making.

5e. Mathematical requirements

In order to be able to develop their skills, knowledge and understanding in A Level Biology, learners need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as indicated in the table of coverage below.

The assessment of quantitative skills will include at least 10% Level 2 (or above) mathematical skills for biology (see later for a definition of 'Level 2' mathematics).

These skills will be applied in the context of the relevant biology.

All mathematical content will be assessed within the lifetime of the specification. Skills shown in **bold** type will only be tested in the full A level course, not the standalone AS level course.

This list of examples is not exhaustive and is not limited to Level 2 examples. These skills could be developed in other areas of specification content from those indicated.

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Biology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M0 – Arithmetic and numerical computation			
M0.1	Recognise and make use of appropriate units in calculations	Learners may be tested on their ability to: • convert between units e.g. mm^3 to cm^3 as part of volumetric calculations • work out the unit for a rate e.g. breathing rate	2.1.1(e), 2.1.2(s), 2.1.4(d), 2.1.4(f), 2.1.5(c), 2.1.5(d), 2.1.5(e), 3.1.1(a), 3.1.1(e), 3.1.2(a), 3.1.2(h), 3.1.3(a), 3.1.3(c), 4.1.1(b), 4.1.1(l), 5.1.2(c), 5.1.5(i), 5.1.5(k), 5.2.1(a), 5.2.1(c), 5.2.1(g), 5.2.2(i), 5.2.2(k), 5.2.2(l), 6.2.1(h), 6.3.1(b), 6.3.2(a)

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Biology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M0.2	Recognise and use expressions in decimal and standard form	Learners may be tested on their ability to: • use an appropriate number of decimal places in calculations, e.g. for a mean • carry out calculations using numbers in standard and ordinary form, e.g. use of magnification • understand standard form when applied to areas such as size of organelles • convert between numbers in standard and ordinary form • understand that significant figures need retaining when making conversions between standard and ordinary form, e.g. 0.0050 mol dm^{-3} is equivalent to 5.0×10^{-3} mol dm^{-3}.	2.1.1(e), 2.1.1(f), 2.1.1(g), 2.1.2(s), 2.1.4(d), 2.1.4(f), 2.1.5(b), 2.1.5(c), 2.1.5(d), 2.1.5(e), 3.1.1(e), 3.1.3(c), 4.1.1(b), 4.1.1(l), 4.2.1(b), 5.1.5(e), 5.1.5(i), 5.1.5(k), 5.2.1(c), 5.2.1(g), 5.2.2(i), 5.2.2(k), 5.2.2(l), 6.1.2(f), 6.2.1(i), 6.3.1(b), 6.3.2(a)
M0.3	Use ratios, fractions and percentages	Learners may be tested on their ability to: • calculate percentage yields • calculate surface area to volume ratio • use scales for measuring • represent phenotypic ratios (monohybrid and dihybrid crosses).	2.1.1(e), 2.1.1(f), 2.1.4(d), 2.1.4(f), 2.1.5(d), 2.1.5(e), 3.1.1(a), 3.1.2(a), 3.1.3(a), 4.1.1(b), 4.1.1(l), 4.2.2(h), 5.1.2(c), 5.1.5(k), 5.2.1(a), 5.2.1(g), 6.1.2(b), 6.1.2(c), 6.2.1(h), 6.2.1(i), 6.3.1(b), 6.3.2(a)
M0.4	Estimate results	Learners may be tested on their ability to: • estimate results to sense check that the calculated values are appropriate.	3.1.1(a), 3.1.1(e), 3.1.2(a), 3.1.3(a), 5.2.1(a), 6.3.1(b), 6.3.2(a)
M0.5	**Use calculators to find and use power, exponential and logarithmic functions**	**Learners may be tested on their ability to:** • **estimate the number of bacteria grown over a certain length of time.**	**6.2.1(h), 6.3.2(a)**

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Biology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M1 – Handling data			
M1.1	Use an appropriate number of significant figures	Learners may be tested on their ability to: • report calculations to an appropriate number of significant figures given raw data quoted to varying numbers of significant figures • understand that calculated results can only be reported to the limits of the least accurate measurement.	2.1.1(e), 2.1.2(s), 2.1.4(d), 2.1.4(f), 2.1.5(c), 2.1.5(d), 2.1.5(e), 3.1.1(a), 3.1.2(a), 3.1.2(h), 3.1.3(a), 3.1.3(c), 4.1.1(b), 4.1.1(l), 4.2.1(c), 4.2.1(d), 4.2.1(e), 5.1.2(c), 5.1.5(e), 5.1.5(i), 5.1.5(k), 5.2.1(c), 5.2.1(g), 5.2.2(i), 5.2.2(k), 5.2.2(l), 6.2.1(h), 6.3.1(b)
M1.2	Find arithmetic means	Learners may be tested on their ability to: • find the mean of a range of data, e.g. the mean number of stomata in the leaves of a plant.	2.1.5(c), 2.1.5(d), 2.1.5(e), 3.1.3(c), 4.1.1(b), 4.1.1(l), 4.2.2(f), 5.1.5(e), 5.1.5(i), 5.1.5(k), 5.2.2(l), 6.2.1(i)
M1.3	Construct and interpret frequency tables and diagrams, bar charts and histograms	Learners may be tested on their ability to: • represent a range of data in a table with clear headings, units and consistent decimal places • interpret data from a variety of tables, e.g. data relating to organ function • plot a range of data in an appropriate format, e.g. enzyme activity over time represented on a graph • interpret data for a variety of graphs, e.g. explain electrocardiogram traces.	2.1.2(s), 2.1.4(d), 2.1.4(f), 2.1.5(c), 2.1.5(d), 2.1.5(e), 3.1.1(e), 3.1.2(h), 3.1.3(c), 4.1.1(b), 4.1.1(g), 4.1.1(l), 4.2.1(b), 4.2.1(f), 4.2.2(f), 5.1.2(c), 5.1.3(c), 5.1.5(a), 5.1.5(e), 5.1.5(i), 5.1.5(k), 5.2.1(c), 5.2.1(g), 5.2.2(i), 5.2.2(k), 5.2.2(l), 6.2.1(h), 6.2.1(i), 6.3.1(b), 6.3.1(e), 6.3.2(a)
M1.4	Understand simple probability	Learners may be tested on their ability to: • use the terms probability and chance appropriately • understand the probability associated with genetic inheritance.	4.2.1(b), 5.1.5(e), 6.1.2(b), 6.1.2(c), 6.2.1(i), 6.3.1(e)

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Biology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M1.5	Understand the principles of sampling as applied to scientific data	Learners may be tested on their ability to: • analyse random data collected by an appropriate means, e.g. use Simpson's index of diversity to calculate the biodiversity of a habitat.	4.1.1(b), 4.1.1(l), 4.2.1(b), 4.2.1(c), 4.2.1(d), 4.2.1(e), 6.3.1(e)
M1.6	Understand the terms mean, median and mode	Learners may be tested on their ability to: • calculate or compare the mean, median and mode of a set of data, e.g. height/mass/ size of a group of organisms.	2.1.5(c), 2.1.5(d), 2.1.5(e), 3.1.3(c), 4.2.1(b), 4.2.2(f), 5.1.5(a), 5.1.5(e), 5.1.5(i), 5.1.5(k), 5.2.2(l), 6.2.1(i), 6.3.1(b)
M1.7	Use a scatter diagram to identify a correlation between two variables	Learners may be tested on their ability to: • interpret a scattergram, e.g. the effect of lifestyle factors on health.	4.1.1(b), 4.1.1(l), 4.2.1(b), 4.2.1(f), 4.2.2(f), 6.3.1(e)
M1.8	Make order of magnitude calculations	Learners may be tested on their ability to: • use and manipulate the magnification formula $magnification = \frac{size\ of\ image}{size\ of\ real\ object}$ •	2.1.1(e)
M1.9	Select and use a statistical test	Learners may be tested on their ability to select and use: • the chi squared test (χ^2) to test the significance of the difference between observed and expected results • the Student's *t*-test • the Spearman's rank correlation coefficient.	4.2.1(b), 5.1.5(e), 6.1.2(c), 6.3.1(e)

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Biology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M1.10	Understand measures of dispersion, including standard deviation and range	Learners may be tested on their ability to: • calculate the standard deviation • understand why standard deviation might be a more useful measure of dispersion for a given set of data e.g. where there is an outlying result.	2.1.5(e), 4.2.1(b), 4.2.2(f), 5.1.5(e), 5.1.5(k), 5.2.2(l), 6.2.1(i), 6.3.1(e)
M1.11	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	Learners may be tested on their ability to: • calculate percentage error where there are uncertainties in measurement.	2.1.4(d), 2.1.4(f), 2.1.5(c), 2.1.5(d), 2.1.5(e), 3.1.3(c), 5.2.1(g)
M2 – Algebra			
M2.1	Understand and use the symbols: $=, <, \ll, \gg, >, \propto, \sim$	No exemplification required.	2.1.5(d), 2.1.5(e), 3.1.1(a), 3.1.2(a), 3.1.3(a), 5.1.2(c), 6.1.2(c)
M2.2	Change the subject of an equation	Learners may be tested on their ability to: • use and manipulate equations, e.g. magnification.	2.1.1(e), 2.1.2(s), 5.2.1(c), 6.1.2(f)
M2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Learners may be tested on their ability to: • use a given equation e.g. Simpson's-index of diversity $D = 1 - \left(\sum\left(\frac{n}{N}\right)^2\right)$	2.1.1(e), 2.1.2(s), 4.2.1(c), 4.2.1(d), 4.2.1(e), 5.2.1(c), 5.2.2(k), 6.1.2(f)
M2.4	Solve algebraic equations	Learners may be tested on their ability to: • solve equations in a biological context, e.g. $\text{cardiac output} = \text{stroke volume} \times \text{heart rate}$	2.1.1(e), 2.1.2(s), 3.1.2(h), 4.2.1(c), 4.2.1(d), 4.2.1(e), 5.2.1(c), 5.2.2(i), 5.2.2(l)
M2.5	**Use logarithms in relation to quantities that range over several orders of magnitude**	**Learners may be tested on their ability to:** • **use a logarithmic scale in the context of microbiology, e.g. growth rate of a microorganism such as yeast.**	**6.2.1(h), 6.3.2(a)**

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Biology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M3 – Graphs			
M3.1	Translate information between graphical, numerical and algebraic forms	Learners may be tested on their ability to: • understand that data may be presented in a number of formats and be able to use these data, e.g. dissociation curves.	2.1.4(d), 2.1.4(f), 2.1.5(c), 2.1.5(d), 2.1.5(e), 3.1.2(j), 3.1.3(c), 4.1.1(b), 4.1.1(l), 4.2.1(f), 5.1.2(c), 5.1.3(c), 5.1.5(e), 5.1.5(k), 5.2.1(g), 5.2.2(i), 6.2.1(h), 6.3.1(e), 6.3.2(a)
M3.2	Plot two variables from experimental or other data	Learners may be tested on their ability to: • select an appropriate format for presenting data, bar charts, histograms, graphs and scattergrams.	2.1.4(d), 2.1.4(f), 2.1.5(c), 2.1.5(d), 2.1.5(e), 3.1.3(c), 4.1.1(b), 4.1.1(l), 4.2.1(b), 5.1.5(e), 5.2.1(g), 5.2.2(i), 5.2.2(l), 6.2.1(h), 6.2.1(i), 6.3.1(e), 6.3.2(a)
M3.3	Understand that $y = mx + c$ represents a linear relationship	Learners may be tested on their ability to: • predict/sketch the shape of a graph with a linear relationship, e.g. the effect of substrate concentration on the rate of an enzyme-controlled reaction with excess enzyme.	2.1.4(d), 2.1.4(f), 2.1.5(c), 2.1.5(d), 3.1.3©, 5.2.2(l)
M3.4	**Determine the intercept of a graph**	**Learners may be tested on their ability to:** • **read off an intercept point from a graph, e.g. compensation point in plants.**	**5.2.1(a), 5.2.1(g), 6.2.1(h)**
M3.5	Calculate rate of change from a graph showing a linear relationship	Learners may be tested on their ability to: • calculate a rate from a graph, e.g. rate of transpiration.	2.1.4(d), 2.1.4(f), 2.1.5(c), 2.1.5(d), 3.1.3(c), 5.2.1(g), 5.2.2(l), 6.2.1(h)
M3.6	Draw and use the slope of a tangent to a curve as a measure of rate of change	Learners may be tested on their ability to: • use this method to measure the gradient of a point on a curve, e.g. amount of product formed plotted against time when the concentration of enzyme is fixed.	2.1.4(d), 2.1.4(f), 2.1.5(c), 2.1.5(d), 3.1.3(c), 5.2.1(g), 5.2.2(l), 6.2.1(h)

	Mathematical skill to be assessed	Exemplification of the mathematical skill in the context of A Level Biology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M4 – Geometry and trigonometry			
M4.1	Calculate the circumferences, surface areas and volumes of regular shapes	Learners may be tested on their ability to: • calculate the circumference and area of a circle • calculate the surface area and volume of rectangular prisms, of cylindrical prisms and of spheres • e.g. calculate the surface area or volume of a cell.	2.1.5(d), 2.1.5(e), 3.1.1(a), 3.1.2(a), 3.1.3(a), 3.1.3(c), 5.2.1(g), 6.2.1(i)

Definition of level 2 mathematics

Within A Level in Biology, 10% of the marks available within written examinations will be for assessment of mathematics (in the context of biology) at a Level 2 standard, or higher. Lower level mathematical skills will still be assessed within examination papers but will not count within the 10% weighting for biology.

The following will be counted as Level 2 (or higher) mathematics:

- application and understanding requiring choice of data or equation to be used
- problem solving involving use of mathematics from different areas of maths and decisions about direction to proceed
- questions involving use of A level mathematical content (as of 2012), e.g. use of logarithmic equations.

The following will not be counted as Level 2 mathematics:

- simple substitution with little choice of equation or data
- structured question formats using GCSE mathematics (based on 2012 GCSE mathematics content).

Additional guidance on the assessment of mathematics within biology is available on the OCR website as a separate resource, the Maths Skills Handbook.

5f. Health and Safety

In UK law, health and safety is primarily the responsibility of the employer. In a school or college the employer could be a local education authority, the governing body or board of trustees. Employees (teachers/lecturers, technicians etc.), have a legal duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 (as amended) and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful microorganisms is carried out, or hazardous chemicals are used or made, the employer must carry out a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found at **http://www.ase.org.uk/resources/health-and-safety-resources/health-and-safety-risk-assessments/**

For members, the CLEAPSS® guide, *PS90*, *Making and recording risk assessments in school science*[1] offers appropriate advice.

Most education employers have adopted nationally available publications as the basis for their Model Risk Assessments.

Where an employer has adopted model risk assessments an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment.

Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the candidates were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded in a "*point of use text* ", for example on schemes of work, published teachers guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed for each practical activity, although a minority of employers may require this.

Where project work or investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or microorganisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting CLEAPSS®.

[1] These, and other CLEAPSS® publications, are on the CLEAPSS® Science Publications website **www.cleapss.org.uk**. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS® go to **www.cleapss.org.uk**.

5g. Practical endorsement

The Practical Endorsement is common across Biology A and Biology B (Advancing Biology). It requires a minimum of 12 practical activities to be completed from the categories defined below. **Fig. 1**.

The practical activities can be completed at any point during the two year A level course at the discretion of the centre. Candidates starting from a standalone AS can count A level practical activities carried out during the AS year towards the A level Practical Endorsement provided that they are appropriately recorded. It is recommended therefore that candidates starting AS maintain a record of practical activities carried out (e.g. this could be in the form of a 'log book' or 'practical portfolio') that could be counted towards the Practical endorsement. For candidates who then decide to follow a full A level, having started from AS, they can carry this record with them into their A level study.

The assessment of practical skills is a compulsory requirement of the course of study for A level qualifications in biology, chemistry and physics. It will appear on all students' certificates as a separately reported result, alongside the overall grade for the qualification. The arrangements for the assessment of practical skills will be common to all awarding organisations. These arrangements will include:

- A minimum of 12 practical activities to be carried out by each student which, together, meet the requirements of Appendices 5b (*Practical skills identified for direct assessment and developed through teaching and learning*, covered in Module **1.2.1**) and 5c (*Use of apparatus and techniques*, covered in Module **1.2.2**) from the prescribed subject content, published by the Department for Education. The required practical activities will be defined by each awarding organisation (see **Fig. 1** and **Table 1**)
- Teachers will assess students against Common Practical Assessment Criteria (CPAC) issued by the awarding organisations. The draft CPAC (see **Table 2**) are based on the requirements of Appendices 5b and 5c of the subject content requirements published by the Department for Education, and define the minimum standard required for the achievement of a pass. The CPAC will be piloted with centres and other stakeholders during autumn 2014 and spring 2015 to ensure that they can be applied consistently and effectively
- Each student will keep an appropriate record of their assessed practical activities
- Students who demonstrate the required standard across all the requirements of the CPAC will receive a 'pass' grade
- There will be no separate assessment of practical skills for AS qualifications
- Students will answer questions in the AS and A level examination papers that assess the requirements of Appendix 5a (*Practical skills identified for indirect assessment and developed through teaching and learning*, covered in Module **1.1**) from the prescribed subject content, published by the Department for Education.

Specifications will be updated to include the final version of the CPAC in spring 2015 and the processes that all awarding organisations will follow to review teacher assessments.

OCR has split the requirements of modules **1.2.1** and **1.2.2** and the Common Practical Assessment Criteria (**Table 2** below) into 12 Practical Activity Groups (PAGs) as defined below (with further detail in **Table 1**). Opportunities for carrying out activities that could count towards the Practical Endorsement are indicated throughout the specification, in the guidance column, by use of the labels **PAG1** to **PAG11**. There are a wide variety of opportunities to assess **PAG12** throughout the specification.

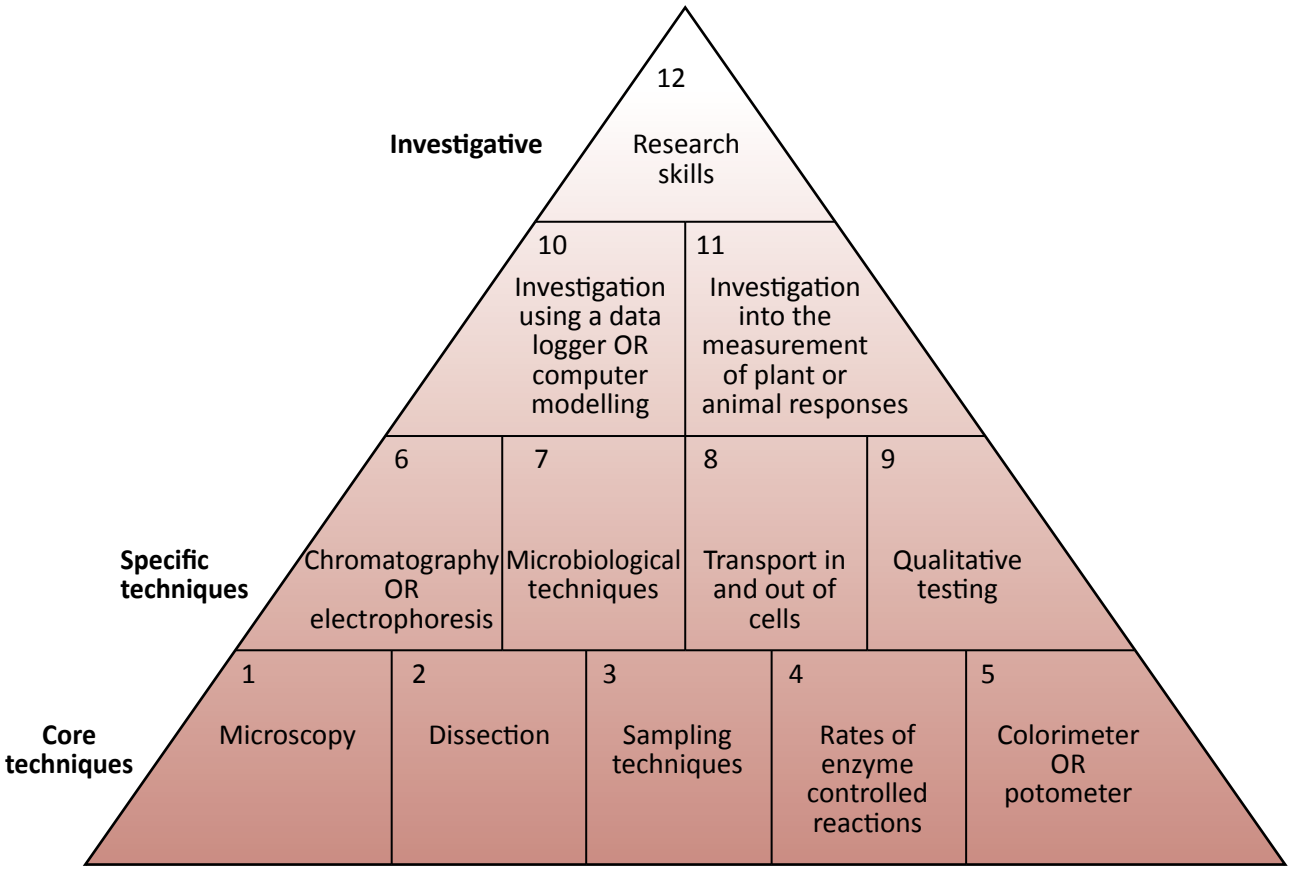

Fig. 1 OCR's Practical Activity Groups (PAGs), also see **Table 1**

Table 1 Practical activity requirements for the OCR Biology Practical Endorsement

Practical activity group (PAG)	Techniques/skills covered (minimum)	Example of a suitable practical activity (a range of examples will be available from the OCR website and centres can devise their own activity)	Specification reference (examples)
1 Microscopy	• Use of a light microscope at high power and low power, use of a graticule[1] • Production of scientific drawings from observations with annotations[2]	Using a light microscope to study mitosis	2.1.1(b), 2.1.1(c), 2.1.1(d), 2.1.1(k), 2.1.6(d), 2.1.6(g), 2.1.6(h), 3.1.1(c), 3.1.1(h), 3.1.3(b), 4.1.1(e), 5.1.2(b), 5.1.2(c), 5.1.4(c), 5.1.5(l)
2 Dissection	• Safe use of instruments for dissection of an animal or plant organ • Use of a light microscope at high power and low power, use of a graticule[1] • Production of scientific drawings from observations with annotations[2]	Dissection of the mammalian heart	3.1.1(g), 3.1.2(c), 3.1.2(e), 3.1.3(b), 5.1.2(c), 6.2.1(a)
3 Sampling techniques	• Use of sampling techniques in fieldwork • Production of scientific drawings from observations with annotations[2]	The calculation of species diversity	4.2.1(b), 6.3.1(e)
4 Rates of enzyme controlled reactions	• Use of appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)[3] • Use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions[4] • Use of ICT such as computer modelling, or data logger to collect data, or use of software to process data [5]	The effect of substrate concentration on the rate of an enzyme controlled reaction	2.1.4(d), 2.1.4(e), 2.1.4(f), 5.2.1(g), 5.2.2(i), 5.2.2(l)

Practical activity group (PAG)	Techniques/skills covered (minimum)	Example of a suitable practical activity (a range of examples will be available from the OCR website and centres can devise their own activity)	Specification reference (examples)
5 Colorimeter or potometer	• Use of appropriate instrumentation to record quantitative measurements, such as a colorimeter • Use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions[4]	The effect of temperature on membrane permeability *An alternative experiment using a potometer could be carried out within this practical activity group*	2.1.2(r), 3.1.3(c)
6 Chromatography OR electrophoresis	• Separation of biological compounds using thin layer / paper chromatography or electrophoresis	Identification of the amino acids in a protein using paper chromatography	2.1.2(s), 5.2.1(c), 6.1.3(e)
7 Microbiological techniques	• Use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions[4] • Use of microbiological aseptic techniques, including the use of agar plates and broth	The effect of antibiotics on bacterial growth	6.2.1(g), 6.2.1(h)
8 Transport in and out of cells	• Use of appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)[3] • Use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions[4] • Use of ICT such as computer modelling, or data logger to collect data, or use of software to process data[5]	An investigation into the water potential of potato	2.1.5(c), 2.1.5(d), 2.1.5(e)
9 Qualitative testing	• Use of laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions[4] • Use of qualitative reagents to identify biological molecules	Qualitative testing for biological molecules – proteins	2.1.2(q), 2.1.3(d), 5.1.2(f)
10 Investigation using a data logger OR computer modelling	• Use of ICT such as computer modelling, or data logger to collect data, or use of software to process data[5]	Investigating DNA structure using RasMol	2.1.2(n), 2.1.3(a), 3.1.1(e), 5.1.5(k), 5.1.5(l), 5.2.1(g), 5.2.2(i), 5.2.2(l), 6.1.3(b)

Practical activity group (PAG)	Techniques/skills covered (minimum)	Example of a suitable practical activity (a range of examples will be available from the OCR website and centres can devise their own activity)	Specification reference (examples)
11 Investigation into the measurement of plant or animal responses	• Safe and ethical use of organisms to measure plant or animal responses and physiological functions	Investigation into the effect of exercise on pulse rate	3.1.3(c), 5.1.1(d), 5.1.5(a), 5.1.5(e), 5.1.5(i), 5.1.5(k), 5.1.5(l), 5.2.1(g), 5.2.2(i), 5.2.2(l)
12 Research skills	• Apply investigative approaches • Use online and offline research skills • Correctly cite sources of information	Investigation into the respiration rate of *Saccharomyces cerevisiae*	

[1,2,3,4,5] These techniques/skills may be covered in any of the groups indicated.

It is expected that the following skills will be developed across <u>all</u> activities, regardless of the exact selection of activities. The ability to:

- safely and correctly use a range of practical equipment and materials **(1.2.1 b)**
- follow written instructions **(1.2.1 c)**
- keep appropriate records of experimental activities **(1.2.1 e)**
- make and record observations/measurements **(1.2.1 d)**
- present information and data in a scientific way **(1.2.1 f)**
- use a wide range of experimental and practical instruments, equipment and techniques **(1.2.1 j)**.

Table 2 Draft Common Practical Assessment Criteria (CPAC) for the assessment of practical competency in A Level Biology (subject to trialling in autumn 2014)

Competency	Practical Mastery
	In order to achieve a **pass**, students will need to have met the following expectations. Students will be expected to develop these competencies through the acquisition of the technical skills specified in Appendix 5 of the DfE subject content for each science subject Biology, Chemistry and Physics. Students can demonstrate these competencies in any practical activity undertaken throughout the course of study. The 12 practical activities prescribed in the subject specification, which cover the requirements of Appendix 5c, will provide opportunities for demonstrating competence in all the skills identified together with the use of apparatus and practical techniques for each subject. Students may work in groups but must be able to demonstrate and record independent evidence of their competency. This must include evidence of independent application of investigative approaches and methods to practical work. Teachers who award a pass to their students need to be confident that the student consistently and routinely exhibits the competencies listed below before completion of the A level course.
(1) Follows written procedures	Correctly follows instructions to carry out the experimental techniques or procedures.
(2) Applies investigative approaches and methods when using instruments and equipment	Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting. Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments when necessary. Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled. Selects appropriate equipment and measurement strategies in order to ensure suitably accurate results.
(3) Safely uses a range of practical equipment and materials	Identifies hazards and assesses risks associated with these hazards when carrying out experimental techniques and procedures in the lab or field. Uses appropriate safety equipment and approaches to minimise risks with minimal prompting. Identifies safety issues and makes adjustments when necessary.
(4) Makes and records observations	Makes accurate observations relevant to the experimental or investigative procedure. Obtains accurate, precise and sufficient data for experimental and investigative procedures and records this methodically using appropriate units and conventions.

(5) Researches, references and reports	Uses appropriate software and/or tools to process data, carry out research and report findings. Sources of information are cited demonstrating that research has taken place, supporting planning and conclusions.

Choice of activity

Centres can include additional skills within an activity beyond those listed as the minimum in **Table 1**. To achieve a Pass within the Practical Endorsement, candidates must have completed a minimum of 12 assessed practical activities (covering all of categories 1 to 12) and achieved the level of competence defined within the Common Practical Assessment Criteria (**Table 2**). The 12 categories can be met by:

(i) using OCR suggested activities (provided as resources)

(ii) through activities devised by the centre that meet the guidelines in **Table 1**

Centres can receive guidance on the suitability of their own practical activities through our free coursework consultancy service (relevant forms are available from our website, www.ocr.org.uk).

Where centres devise their own practical activities to meet the requirements defined above (**Table 1**), the practical activities must meet all of the requirements for each category and be of a level of demand appropriate for A level. Categories 1 to 12 can be achieved through more than one centre devised practical activity, e.g. a centre could split category 6 into two activities of their own (rather than one).

Your checklist

Our aim is to provide you with all the information and support you need to deliver our specifications.

- [ ] Bookmark ocr.org.uk/alevelbiologya for all the latest resources, information and news on AS and A Level Biology A
- [ ] Be among the first to hear about support materials and resources as they become available – register for Biology updates at ocr.org.uk/updates
- [ ] Find out about our professional development at cpdhub.ocr.org.uk
- [ ] View our range of skills guides for use across subjects and qualifications at ocr.org.uk/skillsguides
- [ ] Discover our new online past paper service at ocr.org.uk/examcreator
- [ ] Learn more about Active Results at ocr.org.uk/activeresults
- [ ] Join our Biology social network community for teachers at social.ocr.org.uk

Download high-quality, exciting and innovative AS and A Level Biology resources from ocr.org.uk/alevelbiologya

Free resources and support for our A Level Biology qualification, developed through collaboration between our Biology Subject Specialists, teachers and other subject experts, are available from our website. You can also contact our Biology Subject Specialists for specialist advice, guidance and support, giving you individual service and assistance whenever you need it.

Meet the team at ocr.org.uk/scienceteam and contact them at:
01223 553998
scienceGCE@ocr.org.uk
@OCR_science

To stay up to date with all the relevant news about our qualifications, register for email updates at ocr.org.uk/updates

Science community

The social network is a free platform where teachers can engage with each other – and with us – to find and offer guidance, discover and share ideas, best practice and a range of Science support materials. To sign up, go to social.ocr.org.uk

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