AS AND A-LEVEL BIOLOGY

AS (7401)
A-level (7402)

Specifications
For teaching from September 2015 onwards
For AS exams in May/June 2016 onwards
For A-level exams in May/June 2017 onwards

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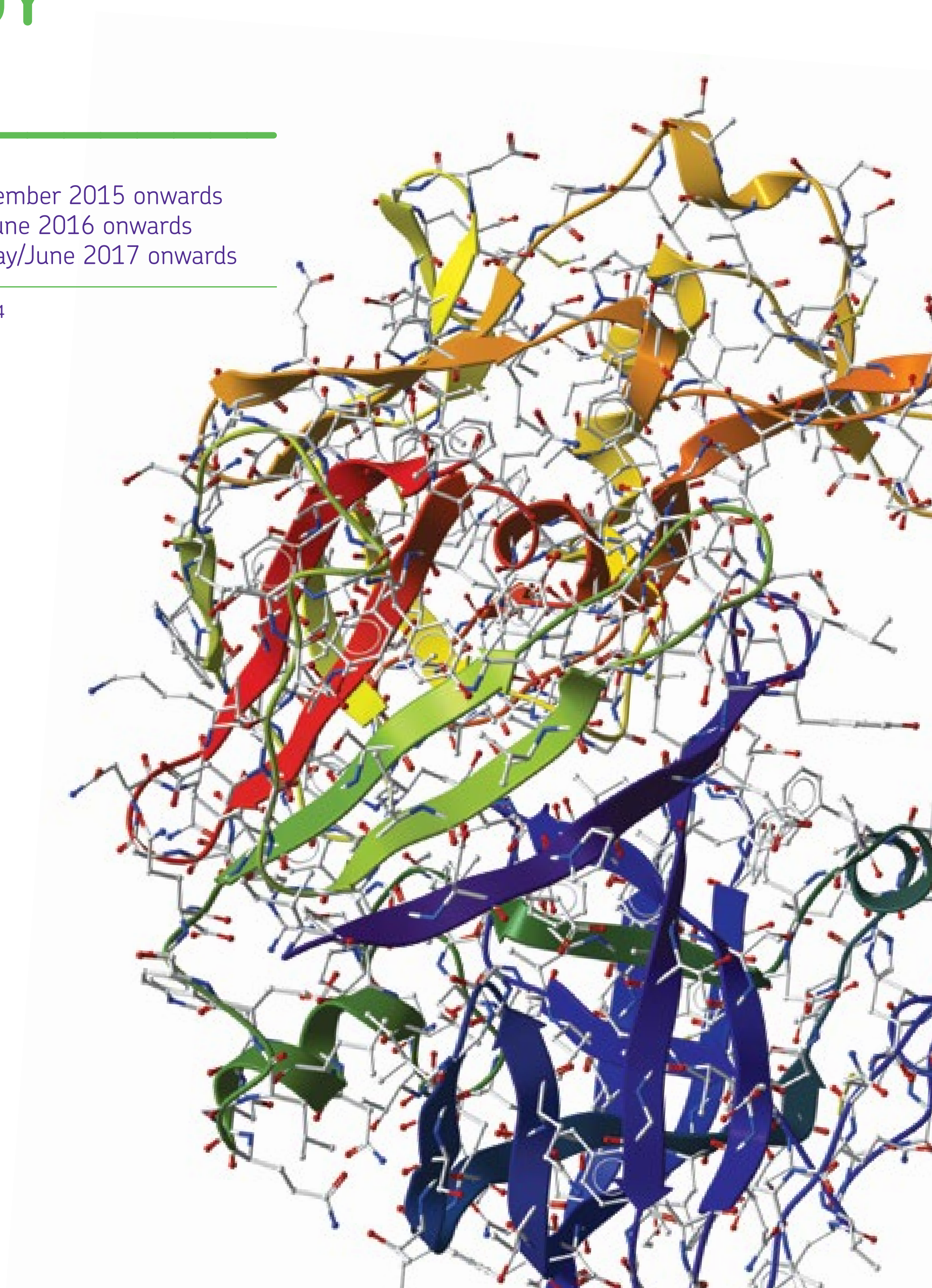

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Are you using the latest version of these specifications?

- You will always find the most up-to-date version of these specifications on our website at aqa.org.uk/7402
- We will write to you if there are significant changes to these specifications.

1 Introduction

1.1 Why choose AQA for AS and A-level Biology

Relevant in the classroom and the real world

We involved over a thousand teachers in developing these specifications, to ensure that the subject content is relevant to real world experiences and is interesting to teach and learn. We've also presented it in a straightforward way, giving you the freedom to teach in the way that works for your students.

A-level Biology is a stepping stone to future study, which is why we also consulted universities to ensure these specifications allow students to develop the skills that they want to see.

This approach has led to specifications that will support you to inspire students, nurture a passion for Biology and lay the groundwork for further study in courses like biological sciences and medicine.

The way you teach – your choice

These specifications have been written in a context-free style. This means that you can select the context and applications that you feel bring the subject alive. You can also teach to your strengths and to your students' needs. To support you, we have produced a range of excellent teaching resources that you can use alongside your own.

Practicals at the heart of science

Like you, we believe that Biology is fundamentally an experimental subject. These specifications provide numerous opportunities to use practical experiences to link theory to reality, and equip students with the essential practical skills they need.

Teach AS and A-level together

We've ensured that the AS and A-level are fully co-teachable. The AS exams include similar questions to those in the A-level, with less difficulty, allowing for future growth. We've created our A-level content with our GCSE in mind to make sure that there is a seamless progression between qualifications. We've also followed ASE guidance on use of scientific terminology across our science subjects.

Assessment success

We've tested our specimen question papers with students, making sure they're interesting, straightforward and clear and hold no hidden surprises. To ensure that your students are rewarded for the biology skills and knowledge they've developed, our exams include:

- accessible assessments allowing students of various abilities to shine
- a choice of two essay questions giving students more opportunities to bring together knowledge of the whole specification (A-level only).

With us, your students will get the results they deserve, from the exam board you trust.

You can find out about all our science qualifications at aqa.org.uk/science

1.2 Support and resources to help you teach

We know that support and resources are vital for your teaching and that you have limited time to find or develop good quality materials. So we've worked with experienced teachers to provide you with a range of resources that will help you confidently plan, teach and prepare for exams.

Teaching resources

We have too many Biology resources to list here so visit aqa.org.uk/7402 to see them all. They include:

- additional practice papers to help students prepare for exams
- guidance on how to plan both the AS and A-level courses with supporting schemes of work for co-teaching
- several AQA-approved student textbooks reviewed by experienced senior examiners
- resources to support key topics, with detailed lesson plans written by experienced teachers
- training courses to help you deliver AQA Biology qualifications
- subject expertise courses for all teachers, from newly-qualified teachers who are just getting started to experienced teachers looking for fresh inspiration.

Preparing for exams

Visit aqa.org.uk/7402 for everything you need to prepare for our exams, including:

- past papers, mark schemes and examiners' reports
- specimen papers and mark schemes for new courses
- Exampro: a searchable bank of past AQA exam questions
- exemplar student answers with examiner commentaries.

Analyse your students' results with Enhanced Results Analysis (ERA)

Find out which questions were the most challenging, how the results compare to previous years and where your students need to improve. ERA, our free online results analysis tool, will help you see where to focus your teaching. Register at aqa.org.uk/era

For information about results, including maintaining standards over time, grade boundaries and our post-results services, visit aqa.org.uk/results

Keep your skills up to date with professional development

Wherever you are in your career, there's always something new to learn. As well as subject-specific training, we offer a range of courses to help boost your skills.

- Improve your teaching skills in areas including differentiation, teaching literacy and meeting Ofsted requirements.
- Prepare for a new role with our leadership and management courses.

You can attend a course at venues around the country, in your school or online – whatever suits your needs and availability. Find out more at coursesandevents.aqa.org.uk

Get help and support

Visit our website for information, guidance, support and resources at aqa.org.uk/7402

You can talk directly to the Biology subject team

E: science-gce@aqa.org.uk

T: 01483 477 756

2 Specification at a glance

These qualifications are linear. Linear means that students will sit all the AS exams at the end of their AS course and all the A-level exams at the end of their A-level course.

2.1 Subject content

Core content

1 Biological molecules (page 11)

2 Cells (page 19)

3 Organisms exchange substances with their environment (page 25)

4 Genetic information, variation and relationships between organisms (page 30)

5 Energy transfers in and between organisms (A-level only) (page 36)

6 Organisms respond to changes in their internal and external environments (A-level only) (page 41)

7 Genetics, populations, evolution and ecosystems (A-level only) (page 47)

8 The control of gene expression (A-level only) (page 51)

2.2 AS

Assessments

Paper 1	+	Paper 2
What's assessed • Any content from topics 1–4, including relevant practical skills		**What's assessed** • Any content from topics 1–4, including relevant practical skills
Assessed • written exam: 1 hour 30 minutes • 75 marks • 50% of AS		**Assessed** • written exam: 1 hour 30 minutes • 75 marks • 50% of AS
Questions • 65 marks: short answer questions • 10 marks: comprehension question		**Questions** • 65 marks: short answer questions • 10 marks: extended response questions

2.3 A-level

Assessments

Paper 1	Paper 2	Paper 3
What's assessed • Any content from topics 1– 4, including relevant practical skills	**What's assessed** • Any content from topics 5–8, including relevant practical skills	**What's assessed** • Any content from topics 1–8, including relevant practical skills
Assessed • written exam: 2 hours • 91 marks • 35% of A-level	**Assessed** • written exam: 2 hours • 91 marks • 35% of A-level	**Assessed** • written exam: 2 hours • 78 marks • 30% of A-level
Questions • 76 marks: a mixture of short and long answer questions • 15 marks: extended response questions	**Questions** • 76 marks: a mixture of short and long answer questions • 15 marks: comprehension question	**Questions** • 38 marks: structured questions, including practical techniques • 15 marks: critical analysis of given experimental data • 25 marks: one essay from a choice of two titles

3 Subject content

Sections 1–4 are designed to be covered in the first year of the A-level and are also the AS subject content. So you can teach AS and A-level together.

Each section begins with an overview, which puts the topic into a broader biological context and encourages understanding of the place of each topic within the subject. The overview is intended to encourage an overarching approach to both the teaching and learning of topic areas. As such, it will not be directly assessed.

These specifications are presented in a two-column format. The left-hand column contains the specification content that all students must cover and that can be assessed in written papers. The right-hand column exemplifies the opportunities for skills to be developed throughout the course. As such, knowledge of individual experiments on the right-hand side is **not** assumed knowledge for the assessment.

The codes in the right-hand column refer to the skills in the relevant appendices. **MS** refers to the Mathematical Skills, **AT** refers to the Apparatus and Techniques and **PS** refers to the Practical Skills.

3.1 Biological molecules

All life on Earth shares a common chemistry. This provides indirect evidence for evolution.

Despite their great variety, the cells of all living organisms contain only a few groups of carbon-based compounds that interact in similar ways.

Carbohydrates are commonly used by cells as respiratory substrates. They also form structural components in plasma membranes and cell walls.

Lipids have many uses, including the bilayer of plasma membranes, certain hormones and as respiratory substrates.

Proteins form many cell structures. They are also important as enzymes, chemical messengers and components of the blood.

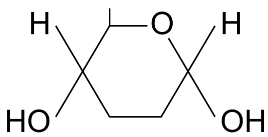
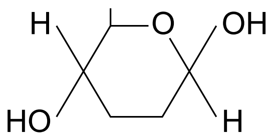
Nucleic acids carry the genetic code for the production of proteins. The genetic code is common to viruses and to all living organisms, providing evidence for evolution.

The most common component of cells is water; hence our search for life elsewhere in the universe involves a search for liquid water.

3.1.1 Monomers and polymers

Content	Opportunities for skills development
The variety of life, both past and present, is extensive, but the biochemical basis of life is similar for all living things. Monomers are the smaller units from which larger molecules are made. Polymers are molecules made from a large number of monomers joined together. Monosaccharides, amino acids and nucleotides are examples of monomers. A condensation reaction joins two molecules together with the formation of a chemical bond and involves the elimination of a molecule of water. A hydrolysis reaction breaks a chemical bond between two molecules and involves the use of a water molecule.	

3.1.2 Carbohydrates

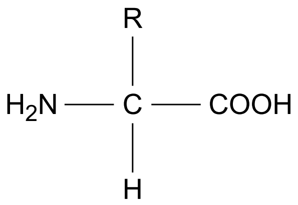
Content	Opportunities for skills development
Monosaccharides are the monomers from which larger carbohydrates are made. Glucose, galactose and fructose are common monosaccharides. A condensation reaction between two monosaccharides forms a glycosidic bond. Disaccharides are formed by the condensation of two monosaccharides: • maltose is a disaccharide formed by condensation of two glucose molecules • sucrose is a disaccharide formed by condensation of a glucose molecule and a fructose molecule • lactose is a disaccharide formed by condensation of a glucose molecule and a galactose molecule. Glucose has two isomers, α-glucose and β-glucose, with structures:  α-glucose  β-glucose Polysaccharides are formed by the condensation of many glucose units. • Glycogen and starch are formed by the condensation of α-glucose. • Cellulose is formed by the condensation of β-glucose. The basic structure and functions of glycogen, starch and cellulose. The relationship of structure to function of these substances in animal cells and plant cells. Biochemical tests using Benedict's solution for reducing sugars and non-reducing sugars and iodine/potassium iodide for starch.	**AT f** Students could use, and interpret the results of, qualitative tests for reducing sugars, non-reducing sugars and starch. **AT g** Students could use chromatography, with known standard solutions, to separate a mixture of monosaccharides and identify their components. **AT c** Students could produce a dilution series of glucose solution and use colorimetric techniques to produce a calibration curve with which to identify the concentration of glucose in an unknown solution.

3.1.3 Lipids

Content	Opportunities for skills development
Triglycerides and phospholipids are two groups of lipid. Triglycerides are formed by the condensation of one molecule of glycerol and three molecules of fatty acid. A condensation reaction between glycerol and a fatty acid (RCOOH) forms an ester bond. The R-group of a fatty acid may be saturated or unsaturated. In phospholipids, one of the fatty acids of a triglyceride is substituted by a phosphate-containing group. The different properties of triglycerides and phospholipids related to their different structures. The emulsion test for lipids. **Students should be able to**: • recognise, from diagrams, saturated and unsaturated fatty acids • explain the different properties of triglycerides and phospholipids.	**AT f** Students could use, and interpret the results of, the emulsion test for lipids.

3.1.4 Proteins

3.1.4.1 General properties of proteins

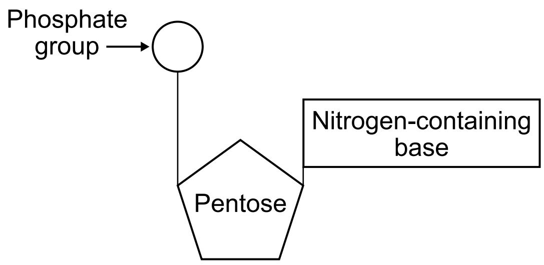
Content	Opportunities for skills development
Amino acids are the monomers from which proteins are made. The general structure of an amino acid as:  where NH2 represents an amine group, COOH represents a carboxyl group and R represents a carbon-containing side chain. The twenty amino acids that are common in all organisms differ only in their side group. A condensation reaction between two amino acids forms a peptide bond. • Dipeptides are formed by the condensation of two amino acids. • Polypeptides are formed by the condensation of many amino acids. A functional protein may contain one or more polypeptides. The role of hydrogen bonds, ionic bonds and disulfide bridges in the structure of proteins. Proteins have a variety of functions within all living organisms. The relationship between primary, secondary, tertiary and quaternary structure, and protein function. The biuret test for proteins. **Students should be able to** relate the structure of proteins to properties of proteins named throughout the specification.	**AT f** Students could use, and interpret the results of, a biuret test for proteins. **AT g** Students could use chromatography with known standard solutions, to separate a mixture of amino acids and identify their components.

3.1.4.2 Many proteins are enzymes

Content	Opportunities for skills development
Each enzyme lowers the activation energy of the reaction it catalyses. The induced-fit model of enzyme action. The properties of an enzyme relate to the tertiary structure of its active site and its ability to combine with complementary substrate(s) to form an enzyme-substrate complex. • The specificity of enzymes • The effects of the following factors on the rate of enzyme-controlled reactions – enzyme concentration, substrate concentration, concentration of competitive and of non-competitive inhibitors, pH and temperature. **Students should be able to:** • appreciate how models of enzyme action have changed over time • appreciate that enzymes catalyse a wide range of intracellular and extracellular reactions that determine structures and functions from cellular to whole-organism level.	**MS 0.5** Students could be given the hydrogen ion concentration of a solution in order to calculate its pH, using the formula: $pH = -log_{10}[H^+]$
Required practical 1: Investigation into the effect of a named variable on the rate of an enzyme-controlled reaction.	**PS 2.4** Students could identify the variables that must be controlled in their investigation into rate of reaction. **PS 3.3** Students could calculate the uncertainty of their measurements of the rate of reaction. **MS 3.2** Students could select an appropriate format for the graphical presentation of the results of their investigation into the rate of enzyme-controlled reactions. **MS 3.6** Students could use a tangent to find the initial rate of an enzyme-controlled reaction.

3.1.5 Nucleic acids are important information-carrying molecules

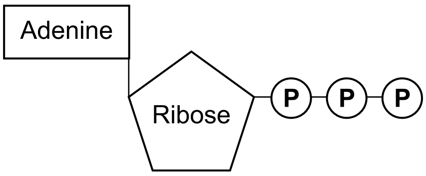
3.1.5.1 Structure of DNA and RNA

Content	Opportunities for skills development
Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are important information-carrying molecules. In all living cells, DNA holds genetic information and RNA transfers genetic information from DNA to the ribosomes. Ribosomes are formed from RNA and proteins. Both DNA and RNA are polymers of nucleotides. Each nucleotide is formed from a pentose, a nitrogen-containing organic base and a phosphate group:  • The components of a DNA nucleotide are deoxyribose, a phosphate group and one of the organic bases adenine, cytosine, guanine or thymine. • The components of an RNA nucleotide are ribose, a phosphate group and one of the organic bases adenine, cytosine, guanine or uracil. • A condensation reaction between two nucleotides forms a phosphodiester bond. A DNA molecule is a double helix with two polynucleotide chains held together by hydrogen bonds between specific complementary base pairs. An RNA molecule is a relatively short polynucleotide chain. **Students should be able to** appreciate that the relative simplicity of DNA led many scientists to doubt that it carried the genetic code.	**MS 0.3** Students could use incomplete information about the frequency of bases on DNA strands to find the frequency of other bases.

3.1.5.2 DNA replication

Content	Opportunities for skills development
The semi-conservative replication of DNA ensures genetic continuity between generations of cells. The process of semi-conservative replication of DNA in terms of: • unwinding of the double helix • breakage of hydrogen bonds between complementary bases in the polynucleotide strands • the role of DNA helicase in unwinding DNA and breaking its hydrogen bonds • attraction of new DNA nucleotides to exposed bases on template strands and base pairing • the role of DNA polymerase in the condensation reaction that joins adjacent nucleotides. **Students should be able to** evaluate the work of scientists in validating the Watson–Crick model of DNA replication.	

3.1.6 ATP

Content	Opportunities for skills development
A single molecule of adenosine triphosphate (ATP) is a nucleotide derivative and is formed from a molecule of ribose, a molecule of adenine and three phosphate groups.  Hydrolysis of ATP to adenosine diphosphate (ADP) and an inorganic phosphate group (Pi) is catalysed by the enzyme ATP hydrolase. • The hydrolysis of ATP can be coupled to energy-requiring reactions within cells. • The inorganic phosphate released during the hydrolysis of ATP can be used to phosphorylate other compounds, often making them more reactive. ATP is resynthesised by the condensation of ADP and Pi. This reaction is catalysed by the enzyme ATP synthase during photosynthesis, or during respiration.	

3.1.7 Water

Content	Opportunities for skills development
Water is a major component of cells. It has several properties that are important in biology. In particular, water: • is a metabolite in many metabolic reactions, including condensation and hydrolysis reactions • is an important solvent in which metabolic reactions occur • has a relatively high heat capacity, buffering changes in temperature • has a relatively large latent heat of vaporisation, providing a cooling effect with little loss of water through evaporation • has strong cohesion between water molecules; this supports columns of water in the tube-like transport cells of plants and produces surface tension where water meets air.	

3.1.8 Inorganic ions

Content	Opportunities for skills development
Inorganic ions occur in solution in the cytoplasm and body fluids of organisms, some in high concentrations and others in very low concentrations. Each type of ion has a specific role, depending on its properties. **Students should be able to** recognise the role of ions in the following topics: hydrogen ions and pH; iron ions as a component of haemoglobin; sodium ions in the co-transport of glucose and amino acids; and phosphate ions as components of DNA and of ATP.	

3.2 Cells

All life on Earth exists as cells. These have basic features in common. Differences between cells are due to the addition of extra features. This provides indirect evidence for evolution.

All cells arise from other cells, by binary fission in prokaryotic cells and by mitosis and meiosis in eukaryotic cells.

All cells have a cell-surface membrane and, in addition, eukaryotic cells have internal membranes. The basic structure of these plasma membranes is the same and enables control of the passage of substances across exchange surfaces by passive or active transport.

Cell-surface membranes contain embedded proteins. Some of these are involved in cell signalling – communication between cells. Others act as antigens, allowing recognition of ‘self’ and ‘foreign’ cells by the immune system. Interactions between different types of cell are involved in disease, recovery from disease and prevention of symptoms occurring at a later date if exposed to the same antigen, or antigen-bearing pathogen.

3.2.1 Cell structure

The cell theory is a unifying concept in biology.

3.2.1.1 Structure of eukaryotic cells

Content	Opportunities for skills development
The structure of eukaryotic cells, restricted to the structure and function of: • cell-surface membrane • nucleus (containing chromosomes, consisting of protein-bound, linear DNA, and one or more nucleoli) • mitochondria • chloroplasts (in plants and algae) • Golgi apparatus and Golgi vesicles • lysosomes (a type of Golgi vesicle that releases lysozymes) • ribosomes • rough endoplasmic reticulum and smooth endoplasmic reticulum • cell wall (in plants, algae and fungi) • cell vacuole (in plants). In complex multicellular organisms, eukaryotic cells become specialised for specific functions. Specialised cells are organised into tissues, tissues into organs and organs into systems. **Students should be able to** apply their knowledge of these features in explaining adaptations of eukaryotic cells.	

3.2.1.2 Structure of prokaryotic cells and of viruses

Content	Opportunities for skills development
Prokaryotic cells are much smaller than eukaryotic cells. They also differ from eukaryotic cells in having: • cytoplasm that lacks membrane-bound organelles • smaller ribosomes • no nucleus; instead they have a single circular DNA molecule that is free in the cytoplasm and is not associated with proteins • a cell wall that contains murein, a glycoprotein. In addition, many prokaryotic cells have: • one or more plasmids • a capsule surrounding the cell • one or more flagella. Details of these structural differences are **not** required. Viruses are acellular and non-living. The structure of virus particles to include genetic material, capsid and attachment protein.	

3.2.1.3 Methods of studying cells

Content	Opportunities for skills development
The principles and limitations of optical microscopes, transmission electron microscopes and scanning electron microscopes. Measuring the size of an object viewed with an optical microscope. The difference between magnification and resolution. Use of the formula: $\text{magnification} = \frac{\text{size of image}}{\text{size of real object}}$ Principles of cell fractionation and ultracentrifugation as used to separate cell components. **Students should be able to** appreciate that there was a considerable period of time during which the scientific community distinguished between artefacts and cell organelles.	**AT d, e and f** Students could use iodine in potassium iodide solution to identify starch grains in plant cells. **MS 1.8**

3.2.2 All cells arise from other cells

<table>
<tr><th>Content</th><th>Opportunities for skills development</th></tr>
<tr><td>
Within multicellular organisms, not all cells retain the ability to divide.
Eukaryotic cells that do retain the ability to divide show a cell cycle.

DNA replication occurs during the interphase of the cell cycle.
Mitosis is the part of the cell cycle in which a eukaryotic cell divides to produce two daughter cells, each with the identical copies of DNA produced by the parent cell during DNA replication.

The behaviour of chromosomes during interphase, prophase, metaphase, anaphase and telophase of mitosis. The role of spindle fibres attached to centromeres in the separation of chromatids.
Division of the cytoplasm (cytokinesis) usually occurs, producing two new cells.
Meiosis is covered in section 3.4.3
Students should be able to:

recognise the stages of the cell cycle: interphase, prophase, metaphase, anaphase and telophase (including cytokinesis)
explain the appearance of cells in each stage of mitosis.

Mitosis is a controlled process. Uncontrolled cell division can lead to the formation of tumours and of cancers. Many cancer treatments are directed at controlling the rate of cell division.
Binary fission in prokaryotic cells involves:

replication of the circular DNA and of plasmids
division of the cytoplasm to produce two daughter cells, each with a single copy of the circular DNA and a variable number of copies of plasmids.

Being non-living, viruses do not undergo cell division. Following injection of their nucleic acid, the infected host cell replicates the virus particles.
</td><td></td></tr>
<tr><td>
Required practical 2: Preparation of stained squashes of cells from plant root tips; set-up and use of an optical microscope to identify the stages of mitosis in these stained squashes and calculation of a mitotic index.
Students should measure the apparent size of cells in the root tip and calculate their actual size using the formula:
$Actual\ size = \frac{size\ of\ image}{magnification}$
</td><td>
AT d and e
MS 0.3
Calculation of a mitotic index.
MS 1.8
</td></tr>
</table>

3.2.3 Transport across cell membranes

Content	Opportunities for skills development
The basic structure of all cell membranes, including cell-surface membranes and the membranes around the cell organelles of eukaryotes, is the same. The arrangement and any movement of phospholipids, proteins, glycoproteins and glycolipids in the fluid-mosaic model of membrane structure. Cholesterol may also be present in cell membranes where it restricts the movement of other molecules making up the membrane. Movement across membranes occurs by: • simple diffusion (involving limitations imposed by the nature of the phospholipid bilayer) • facilitated diffusion (involving the roles of carrier proteins and channel proteins) • osmosis (explained in terms of water potential) • active transport (involving the role of carrier proteins and the importance of the hydrolysis of ATP) • co-transport (illustrated by the absorption of sodium ions and glucose by cells lining the mammalian ileum). Cells may be adapted for rapid transport across their internal or external membranes by an increase in surface area of, or by an increase in the number of protein channels and carrier molecules in, their membranes. **Students should be able to:** • explain the adaptations of specialised cells in relation to the rate of transport across their internal and external membranes • explain how surface area, number of channel or carrier proteins and differences in gradients of concentration or water potential affect the rate of movement across cell membranes.	
Required practical 3: Production of a dilution series of a solute to produce a calibration curve with which to identify the water potential of plant tissue. **Required practical 4:** Investigation into the effect of a named variable on the permeability of cell-surface membranes.	**MS 3.2** Students could plot the data from their investigations in an appropriate format. **MS 3.4** Students could determine the water potential of plant tissues using the intercept of a graph of, eg, water potential of solution against gain/loss of mass.

3.2.4 Cell recognition and the immune system

Content	Opportunities for skills development
Each type of cell has specific molecules on its surface that identify it. These molecules include proteins and enable the immune system to identify: • pathogens • cells from other organisms of the same species • abnormal body cells • toxins. Definition of antigen. The effect of antigen variability on disease and disease prevention. Phagocytosis of pathogens. The subsequent destruction of ingested pathogens by lysozymes. The response of T lymphocytes to a foreign antigen (the cellular response). • The role of antigen-presenting cells in the cellular response. • The role of helper T cells (TH cells) in stimulating cytotoxic T cells (TC cells), B cells and phagocytes. The role of other T cells is **not** required. The response of B lymphocytes to a foreign antigen, clonal selection and the release of monoclonal antibodies (the humoral response). • Definition of antibody. • Antibody structure. • The formation of an antigen-antibody complex, leading to the destruction of the antigen, limited to agglutination and phagocytosis of bacterial cells. • The roles of plasma cells and of memory cells in producing primary and secondary immune responses. The use of vaccines to provide protection for individuals and populations against disease. The concept of herd immunity. The differences between active and passive immunity.	

Content	Opportunities for skills development
Structure of the human immunodeficiency virus (HIV) and its replication in helper T cells. How HIV causes the symptoms of AIDS. Why antibiotics are ineffective against viruses. The use of monoclonal antibodies in: • targeting medication to specific cell types by attaching a therapeutic drug to an antibody • medical diagnosis. Details of the production of monoclonal antibodies is **not** required. Ethical issues associated with the use of vaccines and monoclonal antibodies. The use of antibodies in the ELISA test. **Students should be able to:** • discuss ethical issues associated with the use of vaccines and monoclonal antibodies • evaluate methodology, evidence and data relating to the use of vaccines and monoclonal antibodies.	

3.3 Organisms exchange substances with their environment

The internal environment of a cell or organism is different from its external environment. The exchange of substances between the internal and external environments takes place at exchange surfaces. To truly enter or leave an organism, most substances must cross cell plasma membranes.

In large multicellular organisms, the immediate environment of cells is some form of tissue fluid. Most cells are too far away from exchange surfaces, and from each other, for simple diffusion alone to maintain the composition of tissue fluid within a suitable metabolic range. In large organisms, exchange surfaces are associated with mass transport systems that carry substances between the exchange surfaces and the rest of the body and between parts of the body. Mass transport maintains the final diffusion gradients that bring substances to and from the cell membranes of individual cells. It also helps to maintain the relatively stable environment that is tissue fluid.

3.3.1 Surface area to volume ratio

Content	Opportunities for skills development
The relationship between the size of an organism or structure and its surface area to volume ratio. Changes to body shape and the development of systems in larger organisms as adaptations that facilitate exchange as this ratio reduces. **Students should be able to** appreciate the relationship between surface area to volume ratio and metabolic rate.	**PS 1.1** Students could use agar blocks containing indicator to determine the effect of surface area to volume ratio and concentration gradient on the diffusion of an acid or alkali. **MS 4.1** Students could be given the dimensions of cells with different shapes from which to calculate the surface area to volume ratios of these cells.

3.3.2 Gas exchange

Content	Opportunities for skills development
Adaptations of gas exchange surfaces, shown by gas exchange: • across the body surface of a single-celled organism • in the tracheal system of an insect (tracheae, tracheoles and spiracles) • across the gills of fish (gill lamellae and filaments including the counter-current principle) • by the leaves of dicotyledonous plants (mesophyll and stomata). Structural and functional compromises between the opposing needs for efficient gas exchange and the limitation of water loss shown by terrestrial insects and xerophytic plants. The gross structure of the human gas exchange system limited to the alveoli, bronchioles, bronchi, trachea and lungs. The essential features of the alveolar epithelium as a surface over which gas exchange takes place. Ventilation and the exchange of gases in the lungs. The mechanism of breathing to include the role of the diaphragm and the antagonistic interaction between the external and internal intercostal muscles in bringing about pressure changes in the thoracic cavity. **Students should be able to:** • interpret information relating to the effects of lung disease on gas exchange and/or ventilation • interpret data relating to the effects of pollution and smoking on the incidence of lung disease • analyse and interpret data associated with specific risk factors and the incidence of lung disease • evaluate the way in which experimental data led to statutory restrictions on the sources of risk factors • recognise correlations and causal relationships.	**AT j** Students could dissect mammalian lungs, the gas exchange system of a bony fish or of an insect. **AT d** Students could use an optical microscope to: • examine prepared mounts of gas exchange surfaces of a mammal, fish and insect, or temporary mounts of gills • examine vertical sections through a dicotyledonous leaf. **AT b** Students could use three-way taps, manometers and simple respirometers to measure volumes of air involved in gas exchange. **MS 2.2** Students could be given values of pulmonary ventilation rate (PVR) and one other measure, requiring them to change the subject of the equation: $PVR = tidal\ volume \times breathing\ rate$

3.3.3 Digestion and absorption

Content	Opportunities for skills development
During digestion, large biological molecules are hydrolysed to smaller molecules that can be absorbed across cell membranes. Digestion in mammals of: • carbohydrates by amylases and membrane-bound disaccharidases • lipids by lipase, including the action of bile salts • proteins by endopeptidases, exopeptidases and membrane-bound dipeptidases. Mechanisms for the absorption of the products of digestion by cells lining the ileum of mammals, to include: • co-transport mechanisms for the absorption of amino acids and of monosaccharides • the role of micelles in the absorption of lipids.	**PS 1.1** Students could: • design and carry out investigations into the effect of a pH or bile salts on the rate of reaction catalysed by a digestive enzyme • use Visking tubing models to investigate the absorption of the products of digestion.

3.3.4 Mass transport

Over large distances, efficient movement of substance to and from exchange surfaces is provided by mass transport.

3.3.4.1 Mass transport in animals

Content	Opportunities for skills development
The haemoglobins are a group of chemically similar molecules found in many different organisms. Haemoglobin is a protein with a quaternary structure. The role of haemoglobin and red blood cells in the transport of oxygen. The loading, transport and unloading of oxygen in relation to the oxyhaemoglobin dissociation curve. The cooperative nature of oxygen binding to show that the change in shape of haemoglobin caused by binding of the first oxygens makes the binding of further oxygens easier. The effects of carbon dioxide concentration on the dissociation of oxyhaemoglobin (the Bohr effect). Many animals are adapted to their environment by possessing different types of haemoglobin with different oxygen transport properties. The general pattern of blood circulation in a mammal. Names are required only of the coronary arteries and of the blood vessels entering and leaving the heart, lungs and kidneys. The gross structure of the human heart. Pressure and volume changes and associated valve movements during the cardiac cycle that maintain a unidirectional flow of blood. The structure of arteries, arterioles and veins in relation to their function. The structure of capillaries and the importance of capillary beds as exchange surfaces. The formation of tissue fluid and its return to the circulatory system. **Students should be able to:** • analyse and interpret data relating to pressure and volume changes during the cardiac cycle • analyse and interpret data associated with specific risk factors and the incidence of cardiovascular disease • evaluate conflicting evidence associated with risk factors affecting cardiovascular disease • recognise correlations and causal relationships.	**AT h** Students could design and carry out an investigation into the effect of a named variable on human pulse rate or on the heart rate of an invertebrate, such as *Daphnia*. **MS 2.2** Students could be given values of cardiac output (CO) and one other measure, requiring them to change the subject of the equation: $CO = stroke\ volume \times heart\ rate$
Required practical 5: Dissection of animal or plant gas exchange system or mass transport system or of organ within such a system.	**AT j**

3.3.4.2 Mass transport in plants

Content	Opportunities for skills development
Xylem as the tissue that transports water in the stem and leaves of plants. The cohesion-tension theory of water transport in the xylem. Phloem as the tissue that transports organic substances in plants. The mass flow hypothesis for the mechanism of translocation in plants. The use of tracers and ringing experiments to investigate transport in plants. **Students should be able to:** • recognise correlations and causal relationships • interpret evidence from tracer and ringing experiments and to evaluate the evidence for and against the mass flow hypothesis.	**AT b** Students could set up and use a potometer to investigate the effect of a named environmental variable on the rate of transpiration.

3.4 Genetic information, variation and relationships between organisms

Biological diversity – biodiversity – is reflected in the vast number of species of organisms, in the variation of individual characteristics within a single species and in the variation of cell types within a single multicellular organism.

Differences between species reflect genetic differences. Differences between individuals within a species could be the result of genetic factors, of environmental factors, or a combination of both.

A gene is a section of DNA located at a particular site on a DNA molecule, called its locus. The base sequence of each gene carries the genetic code that determines the sequence of amino acids during protein synthesis. The genetic code is the same in all organisms, providing indirect evidence for evolution.

Genetic diversity within a species can be caused by gene mutation, chromosome mutation or random factors associated with meiosis and fertilisation. This genetic diversity is acted upon by natural selection, resulting in species becoming better adapted to their environment.

Variation within a species can be measured using differences in the base sequence of DNA or in the amino acid sequence of proteins.

Biodiversity within a community can be measured using species richness and an index of diversity.

3.4.1 DNA, genes and chromosomes

Content	Opportunities for skills development
In prokaryotic cells, DNA molecules are short, circular and not associated with proteins. In the nucleus of eukaryotic cells, DNA molecules are very long, linear and associated with proteins, called histones. Together a DNA molecule and its associated proteins form a chromosome. The mitochondria and chloroplasts of eukaryotic cells also contain DNA which, like the DNA of prokaryotes, is short, circular and not associated with protein. A gene is a base sequence of DNA that codes for: • the amino acid sequence of a polypeptide • a functional RNA (including ribosomal RNA and tRNAs). A gene occupies a fixed position, called a locus, on a particular DNA molecule. A sequence of three DNA bases, called a triplet, codes for a specific amino acid. The genetic code is universal, non-overlapping and degenerate. In eukaryotes, much of the nuclear DNA does not code for polypeptides. There are, for example, non-coding multiple repeats of base sequences between genes. Even within a gene only some sequences, called exons, code for amino acid sequences. Within the gene, these exons are separated by one or more non-coding sequences, called introns.	

3.4.2 DNA and protein synthesis

Content	Opportunities for skills development
The concept of the genome as the complete set of genes in a cell and of the proteome as the full range of proteins that a cell is able to produce. The structure of molecules of messenger RNA (mRNA) and of transfer RNA (tRNA). Transcription as the production of mRNA from DNA. The role of RNA polymerase in joining mRNA nucleotides. • In prokaryotes, transcription results directly in the production of mRNA from DNA. • In eukaryotes, transcription results in the production of pre-mRNA; this is then spliced to form mRNA. Translation as the production of polypeptides from the sequence of codons carried by mRNA. The roles of ribosomes, tRNA and ATP. **Students should be able to:** • relate the base sequence of nucleic acids to the amino acid sequence of polypeptides, when provided with suitable data about the genetic code • interpret data from experimental work investigating the role of nucleic acids. Students will **not** be required to recall in written papers specific codons and the amino acids for which they code.	

3.4.3 Genetic diversity can arise as a result of mutation or during meiosis

Content	Opportunities for skills development
Gene mutations involve a change in the base sequence of chromosomes. They can arise spontaneously during DNA replication and include base deletion and base substitution. Due to the degenerate nature of the genetic code, not all base substitutions cause a change in the sequence of encoded amino acids. Mutagenic agents can increase the rate of gene mutation. Mutations in the number of chromosomes can arise spontaneously by chromosome non-disjunction during meiosis. Meiosis produces daughter cells that are genetically different from each other. The process of meiosis only in sufficient detail to show how: • two nuclear divisions result usually in the formation of four haploid daughter cells from a single diploid parent cell • genetically different daughter cells result from the independent segregation of homologous chromosomes • crossing over between homologous chromosomes results in further genetic variation among daughter cells. **Students should be able to:** • complete diagrams showing the chromosome content of cells after the first and second meiotic division, when given the chromosome content of the parent cell • explain the different outcome of mitosis and meiosis • recognise where meiosis occurs when given information about an unfamiliar life cycle • explain how random fertilisation of haploid gametes further increases genetic variation within a species.	**AT d** Students could examine meiosis in prepared slides of suitable plant or animal tissue. **MS 0.5** Students could: • use the expression 2^n to calculate the possible number of different combinations of chromosomes following meiosis, without crossing over • derive a formula from this to calculate the possible number of different combinations of chromosomes following random fertilisation of two gametes, where *n* is the number of homologous chromosomes pairs.

3.4.4 Genetic diversity and adaptation

Content	Opportunities for skills development
Genetic diversity as the number of different alleles of genes in a population. Genetic diversity is a factor enabling natural selection to occur. The principles of natural selection in the evolution of populations. • Random mutation can result in new alleles of a gene. • Many mutations are harmful but, in certain environments, the new allele of a gene might benefit its possessor, leading to increased reproductive success. • The advantageous allele is inherited by members of the next generation. • As a result, over many generations, the new allele increases in frequency in the population. Directional selection, exemplified by antibiotic resistance in bacteria, and stabilising selection, exemplified by human birth weights. Natural selection results in species that are better adapted to their environment. These adaptations may be anatomical, physiological or behavioural. **Students should be able to:** • use unfamiliar information to explain how selection produces changes within a population of a species • interpret data relating to the effect of selection in producing change within populations • show understanding that adaptation and selection are major factors in evolution and contribute to the diversity of living organisms.	**MS 2.5** Students could use a logarithmic scale when dealing with data relating to large numbers of bacteria in a culture.
Required practical 6: Use of aseptic techniques to investigate the effect of antimicrobial substances on microbial growth.	**AT i**

3.4.5 Species and taxonomy

Content	Opportunities for skills development
Two organisms belong to the same species if they are able to produce fertile offspring. Courtship behaviour as a necessary precursor to successful mating. The role of courtship in species recognition. A phylogenetic classification system attempts to arrange species into groups based on their evolutionary origins and relationships. It uses a hierarchy in which smaller groups are placed within larger groups, with no overlap between groups. Each group is called a taxon (plural taxa). One hierarchy comprises the taxa: domain, kingdom, phylum, class, order, family, genus and species. Each species is universally identified by a binomial consisting of the name of its genus and species, eg, *Homo sapiens*. Recall of different taxonomic systems, such as the three domain or five kingdom systems, will **not** be required. **Students should be able to** appreciate that advances in immunology and genome sequencing help to clarify evolutionary relationships between organisms.	

3.4.6 Biodiversity within a community

Content	Opportunities for skills development
Biodiversity can relate to a range of habitats, from a small local habitat to the Earth. Species richness is a measure of the number of different species in a community. An index of diversity describes the relationship between the number of species in a community and the number of individuals in each species. Calculation of an index of diversity (d) from the formula $d = \frac{N(N-1)}{\Sigma n(n-1)}$ where N = total number of organisms of all species and n = total number of organisms of each species. Farming techniques reduce biodiversity. The balance between conservation and farming.	**MS 2.3** Students could be given data from which to calculate an index of diversity and interpret the significance of the calculated value of the index.

3.4.7 Investigating diversity

<table>
<tr><th>Content</th><th>Opportunities for skills development</th></tr>
<tr><td>
Genetic diversity within, or between species, can be made by comparing:

the frequency of measurable or observable characteristics
the base sequence of DNA
the base sequence of mRNA
the amino acid sequence of the proteins encoded by DNA and mRNA.

Students should be able to:

interpret data relating to similarities and differences in the base sequences of DNA and in the amino acid sequences of proteins to suggest relationships between different organisms within a species and between species
appreciate that gene technology has caused a change in the methods of investigating genetic diversity; inferring DNA differences from measurable or observable characteristics has been replaced by direct investigation of DNA sequences.

Knowledge of gene technologies will not be tested.
Quantitative investigations of variation within a species involve:

collecting data from random samples
calculating a mean value of the collected data and the standard deviation of that mean
interpreting mean values and their standard deviations.

Students will not be required to calculate standard deviations in written papers.
</td><td>
AT k
Students could:

design appropriate methods to ensure random sampling
carry out random sampling within a single population
use random samples to investigate the effect of position on the growth of leaves.

MS 1.2
Students could use standard scientific calculators to calculate the mean values of data they have collected or have been given.
MS 1.10
Students could calculate, and interpret the values of, the standard deviations of their mean values.
</td></tr>
</table>

3.5 Energy transfers in and between organisms (A-level only)

Life depends on continuous transfers of energy.

In photosynthesis, light is absorbed by chlorophyll and this is linked to the production of ATP.

In respiration, various substances are used as respiratory substrates. The hydrolysis of these respiratory substrates is linked to the production of ATP.

In both respiration and photosynthesis, ATP production occurs when protons diffuse down an electrochemical gradient through molecules of the enzyme ATP synthase, embedded in the membranes of cellular organelles.

The process of photosynthesis is common in all photoautotrophic organisms and the process of respiration is common in all organisms, providing indirect evidence for evolution.

In communities, the biological molecules produced by photosynthesis are consumed by other organisms, including animals, bacteria and fungi. Some of these are used as respiratory substrates by these consumers.

Photosynthesis and respiration are not 100% efficient. The transfer of biomass and its stored chemical energy in a community from one organism to a consumer is also not 100% efficient.

3.5.1 Photosynthesis (A-level only)

Content	Opportunities for skills development
The light-dependent reaction in such detail as to show that: • chlorophyll absorbs light, leading to photoionisation of chlorophyll • some of the energy from electrons released during photoionisation is conserved in the production of ATP and reduced NADP • the production of ATP involves electron transfer associated with the transfer of electrons down the electron transfer chain and passage of protons across chloroplast membranes and is catalysed by ATP synthase embedded in these membranes (chemiosomotic theory) • photolysis of water produces protons, electrons and oxygen. The light-independent reaction uses reduced NADP from the light-dependent reaction to form a simple sugar. The hydrolysis of ATP, also from the light-dependent reaction, provides the additional energy for this reaction. The light-independent reaction in such detail as to show that: • carbon dioxide reacts with ribulose bisphosphate (RuBP) to form two molecules of glycerate 3-phosphate (GP). This reaction is catalysed by the enzyme rubisco • ATP and reduced NADP from the light-dependent reaction are used to reduce GP to triose phosphate • some of the triose phosphate is used to regenerate RuBP in the Calvin cycle • some of the triose phosphate is converted to useful organic substances. **Students should be able to:** • identify environmental factors that limit the rate of photosynthesis • evaluate data relating to common agricultural practices used to overcome the effect of these limiting factors.	**AT a** Students could devise and carry out experiments to investigate the effect of named environmental variables on the rate of photosynthesis using aquatic plants, algae or immobilised algal beads.
Required practical 7: Use of chromatography to investigate the pigments isolated from leaves of different plants, eg, leaves from shade-tolerant and shade-intolerant plants or leaves of different colours. **Required practical 8:** Investigation into the effect of a named factor on the rate of dehydrogenase activity in extracts of chloroplasts.	**AT g and b**

3.5.2 Respiration (A-level only)

Content	Opportunities for skills development
Respiration produces ATP. Glycolysis is the first stage of anaerobic and aerobic respiration. It occurs in the cytoplasm and is an anaerobic process. Glycolysis involves the following stages: • phosphorylation of glucose to glucose phosphate, using ATP • production of triose phosphate • oxidation of triose phosphate to pyruvate with a net gain of ATP and reduced NAD. If respiration is only anaerobic, pyruvate can be converted to ethanol or lactate using reduced NAD. The oxidised NAD produced in this way can be used in further glycolysis. If respiration is aerobic, pyruvate from glycolysis enters the mitochondrial matrix by active transport. Aerobic respiration in such detail as to show that: • pyruvate is oxidised to acetate, producing reduced NAD in the process • acetate combines with coenzyme A in the link reaction to produce acetylcoenzyme A • acetylcoenzyme A reacts with a four-carbon molecule, releasing coenzyme A and producing a six-carbon molecule that enters the Krebs cycle • in a series of oxidation-reduction reactions, the Krebs cycle generates reduced coenzymes and ATP by substrate-level phosphorylation, and carbon dioxide is lost • synthesis of ATP by oxidative phosphorylation is associated with the transfer of electrons down the electron transfer chain and passage of protons across inner mitochondrial membranes and is catalysed by ATP synthase embedded in these membranes (chemiosomotic theory) • other respiratory substrates include the breakdown products of lipids and amino acids, which enter the Krebs cycle.	**AT b** Students could use a redox indicator to investigate dehydrogenase activity.
Required practical 9: Investigation into the effect of a named variable on the rate of respiration of cultures of single-celled organisms.	**AT b and i**

3.5.3 Energy and ecosystems (A-level only)

Content	Opportunities for skills development
In any ecosystem, plants synthesise organic compounds from atmospheric, or aquatic, carbon dioxide. Most of the sugars synthesised by plants are used by the plant as respiratory substrates. The rest are used to make other groups of biological molecules. These biological molecules form the biomass of the plants. Biomass can be measured in terms of mass of carbon or dry mass of tissue per given area per given time. The chemical energy store in dry biomass can be estimated using calorimetry. Gross primary production (GPP) is the chemical energy store in plant biomass, in a given area or volume, in a given time. Net primary production (NPP) is the chemical energy store in plant biomass after respiratory losses to the environment have been taken into account, ie $NPP = GPP - R$ where GPP represents gross productivity and R represents respiratory losses to the environment. This net primary production is available for plant growth and reproduction. It is also available to other trophic levels in the ecosystem, such as herbivores and decomposers. The net production of consumers (N), such as animals, can be calculated as: $N = I - (F + R)$ where I represents the chemical energy store in ingested food, F represents the chemical energy lost to the environment in faeces and urine and R represents the respiratory losses to the environment. **Students should be able to** appreciate the ways in which productivity is affected by farming practices designed to increase the efficiency of energy transfer by: • simplifying food webs to reduce energy losses to non-human food chains • reducing respiratory losses within a human food chain.	**MS 0.1** Students could be given data from which to calculate gross primary productivity and to derive the appropriate units. **AT a** Students could carry out investigations to find the dry mass of plant samples or the energy released by samples of plant biomass. **MS 2.4** Students could be given data from which to calculate: • the net productivity of producers or consumers from given data • the efficiency of energy transfers within ecosystems. **MS 0.3** Students could be given data from which to calculate percentage yields.

3.5.4 Nutrient cycles (A-level only)

<table>
<tr><th>Content</th><th>Opportunities for skills development</th></tr>
<tr><td>Nutrients are recycled within natural ecosystems, exemplified by the nitrogen cycle and the phosphorus cycle.

Microorganisms play a vital role in recycling chemical elements such as phosphorus and nitrogen.
• The role of saprobionts in decomposition.
• The role of mycorrhizae in facilitating the uptake of water and inorganic ions by plants.
• The role of bacteria in the nitrogen cycle in sufficient detail to illustrate the processes of saprobiotic nutrition, ammonification, nitrification, nitrogen fixation and denitrification.

(The names of individual species of bacteria are not required).

The use of natural and artificial fertilisers to replace the nitrates and phosphates lost by harvesting plants and removing livestock.

The environmental issues arising from the use of fertilisers including leaching and eutrophication.</td><td>PS 1.1

Students could devise investigations into the effect of named minerals on plant growth.</td></tr>
</table>

3.6 Organisms respond to changes in their internal and external environments (A-level only)

A stimulus is a change in the internal or external environment. A receptor detects a stimulus. A coordinator formulates a suitable response to a stimulus. An effector produces a response.

Receptors are specific to one type of stimulus.

Nerve cells pass electrical impulses along their length. A nerve impulse is specific to a target cell only because it releases a chemical messenger directly onto it, producing a response that is usually rapid, short-lived and localised.

In contrast, mammalian hormones stimulate their target cells via the blood system. They are specific to the tertiary structure of receptors on their target cells and produce responses that are usually slow, long-lasting and widespread.

Plants control their response using hormone-like growth substances.

3.6.1 Stimuli, both internal and external, are detected and lead to a response (A-level only)

3.6.1.1 Survival and response (A-level only)

Content	Opportunities for skills development
Organisms increase their chance of survival by responding to changes in their environment. In flowering plants, specific growth factors move from growing regions to other tissues, where they regulate growth in response to directional stimuli. The effect of different concentrations of indoleacetic acid (IAA) on cell elongation in the roots and shoots of flowering plants as an explanation of gravitropism and phototropism in flowering plants. Taxes and kineses as simple responses that can maintain a mobile organism in a favourable environment. The protective effect of a simple reflex, exemplified by a three-neurone simple reflex. Details of spinal cord and dorsal and ventral roots are **not** required.	**AT h** Students could design and carry out investigations into the effects of indoleacetic acid on root growth in seedlings.
Required practical 10: Investigation into the effect of an environmental variable on the movement of an animal using either a choice chamber or a maze.	**AT h**

3.6.1.2 Receptors (A-level only)

Content	Opportunities for skills development
The Pacinian corpuscle should be used as an example of a receptor to illustrate that: • receptors respond only to specific stimuli • stimulation of a receptor leads to the establishment of a generator potential. The basic structure of a Pacinian corpuscle. Deformation of stretch-mediated sodium ion channels in a Pacinian corpuscle leads to the establishment of a generator potential. The human retina in sufficient detail to show how differences in sensitivity to light, sensitivity to colour and visual acuity are explained by differences in the optical pigments of rods and cones and the connections rods and cones make in the optic nerve.	**AT h** Students could design and carry out investigations into: • the sensitivity of temperature receptors in human skin • habituation of touch receptors in human skin • resolution of touch receptors in human skin.

3.6.1.3 Control of heart rate (A-level only)

Content	Opportunities for skills development
Myogenic stimulation of the heart and transmission of a subsequent wave of electrical activity. The roles of the sinoatrial node (SAN), atrioventricular node (AVN) and Purkyne tissue in the bundle of His. The roles and locations of chemoreceptors and pressure receptors and the roles of the autonomic nervous system and effectors in controlling heart rate.	**AT h** Students could design and carry out an investigation into the effect of a named variable on human pulse rate. **MS 2.2** Students could use values of heart rate (*R*) and stroke volume (*V*) to calculate cardiac output (*CO*), using the formula $CO = R \times V$

3.6.2 Nervous coordination (A-level only)

3.6.2.1 Nerve impulses (A-level only)

Content	Opportunities for skills development
The structure of a myelinated motor neurone. The establishment of a resting potential in terms of differential membrane permeability, electrochemical gradients and the movement of sodium ions and potassium ions. Changes in membrane permeability lead to depolarisation and the generation of an action potential. The all-or-nothing principle. The passage of an action potential along non-myelinated and myelinated axons, resulting in nerve impulses. The nature and importance of the refractory period in producing discrete impulses and in limiting the frequency of impulse transmission. Factors affecting the speed of conductance: myelination and saltatory conduction; axon diameter; temperature.	**MS 0.2** Students could use appropriate units when calculating the maximum frequency of impulse conduction given the refractory period of a neurone.

3.6.2.2 Synaptic transmission (A-level only)

Content	Opportunities for skills development
The detailed structure of a synapse and of a neuromuscular junction. The sequence of events involved in transmission across a cholinergic synapse in sufficient detail to explain: • unidirectionality • temporal and spatial summation • inhibition by inhibitory synapses. A comparison of transmission across a cholinergic synapse and across a neuromuscular junction. **Students should be able to** use information provided to predict and explain the effects of specific drugs on a synapse. (Recall of the names and mode of action of individual drugs will **not** be required.)	

3.6.3 Skeletal muscles are stimulated to contract by nerves and act as effectors (A-level only)

Content	Opportunities for skills development
Muscles act in antagonistic pairs against an incompressible skeleton. Gross and microscopic structure of skeletal muscle. The ultrastructure of a myofibril. The roles of actin, myosin, calcium ions and ATP in myofibril contraction. The roles of calcium ions and tropomyosin in the cycle of actinomyosin bridge formation. (The role of troponin is **not** required.) The roles of ATP and phosphocreatine in muscle contraction. The structure, location and general properties of slow and fast skeletal muscle fibres.	**AT d** Students could examine prepared slides of skeletal muscle using an optical microscope. **AT h** Students could investigate the effect of repeated muscular contraction on the rate of muscle fatigue in human vounteers.

3.6.4 Homeostasis is the maintenance of a stable internal environment (A-level only)

3.6.4.1 Principles of homeostasis and negative feedback (A-level only)

Content	Opportunities for skills development
Homeostasis in mammals involves physiological control systems that maintain the internal environment within restricted limits. The importance of maintaining a stable core temperature and stable blood pH in relation to enzyme activity. The importance of maintaining a stable blood glucose concentration in terms of availability of respiratory substrate and of the water potential of blood. Negative feedback restores systems to their original level. The possession of separate mechanisms involving negative feedback controls departures in different directions from the original state, giving a greater degree of control. **Students should be able to** interpret information relating to examples of negative and positive feedback.	

3.6.4.2 Control of blood glucose concentration (A-level only)

<table>
<tr><th>Content</th><th>Opportunities for skills development</th></tr>
<tr><td>The factors that influence blood glucose concentration.

The role of the liver in glycogenesis, glycogenolysis and gluconeogenesis.

The action of insulin by:
• attaching to receptors on the surfaces of target cells
• controlling the uptake of glucose by regulating the inclusion of channel proteins in the surface membranes of target cells
• activating enzymes involved in the conversion of glucose to glycogen.

The action of glucagon by:
• attaching to receptors on the surfaces of target cells
• activating enzymes involved in the conversion of glycogen to glucose
• activating enzymes involved in the conversion of glycerol and amino acids into glucose.

The role of adrenaline by:
• attaching to receptors on the surfaces of target cells
• activating enzymes involved in the conversion of glycogen to glucose.

The second messenger model of adrenaline and glucagon action, involving adenyl cyclate, cyclic AMP (cAMP) and protein kinase.

The causes of types I and II diabetes and their control by insulin and/ or manipulation of the diet.

Students should be able to evaluate the positions of health advisers and the food industry in relation to the increased incidence of type II diabetes.</td><td></td></tr>
<tr><td>Required practical 11: Production of a dilution series of a glucose solution and use of colorimetric techniques to produce a calibration curve with which to identify the concentration of glucose in an unknown ‘urine’ sample.</td><td>AT b and c</td></tr>
</table>

3.6.4.3 Control of blood water potential (A-level only)

Content	Opportunities for skills development
Osmoregulation as control of the water potential of the blood. The roles of the hypothalamus, posterior pituitary and antidiuretic hormone (ADH) in osmoregulation. The structure of the nephron and its role in: • the formation of glomerular filtrate • reabsorption of glucose and water by the proximal convoluted tubule • maintaining a gradient of sodium ions in the medulla by the loop of Henle • reabsorption of water by the distal convoluted tubule and collecting ducts.	

3.7 Genetics, populations, evolution and ecosystems (A-level only)

The theory of evolution underpins modern Biology. All new species arise from an existing species. This results in different species sharing a common ancestry, as represented in phylogenetic classification. Common ancestry can explain the similarities between all living organisms, such as common chemistry (eg all proteins made from the same 20 or so amino acids), physiological pathways (eg anaerobic respiration), cell structure, DNA as the genetic material and a 'universal' genetic code.

The individuals of a species share the same genes but (usually) different combinations of alleles of these genes. An individual inherits alleles from their parent or parents.

A species exists as one or more populations. There is variation in the phenotypes of organisms in a population, due to genetic and environmental factors. Two forces affect genetic variation in populations: genetic drift and natural selection. Genetic drift can cause changes in allele frequency in small populations. Natural selection occurs when alleles that enhance the fitness of the individuals that carry them rise in frequency. A change in the allele frequency of a population is evolution.

If a population becomes isolated from other populations of the same species, there will be no gene flow between the isolated population and the others. This may lead to the accumulation of genetic differences in the isolated population, compared with the other populations. These differences may ultimately lead to organisms in the isolated population becoming unable to breed and produce fertile offspring with organisms from the other populations. This reproductive isolation means that a new species has evolved.

Populations of different species live in communities. Competition occurs within and between these populations for the means of survival. Within a single community, one population is affected by other populations, the biotic factors, in its environment. Populations within communities are also affected by, and in turn affect, the abiotic (physicochemical) factors in an ecosystem.

3.7.1 Inheritance (A-level only)

Content	Opportunities for skills development
The genotype is the genetic constitution of an organism. The phenotype is the expression of this genetic constitution and its interaction with the environment. There may be many alleles of a single gene. Alleles may be dominant, recessive or codominant. In a diploid organism, the alleles at a specific locus may be either homozygous or heterozygous. The use of fully labelled genetic diagrams to interpret, or predict, the results of: • monohybrid and dihybrid crosses involving dominant, recessive and codominant alleles • crosses involving sex-linkage, autosomal linkage, multiple alleles and epistasis. Use of the chi-squared (X^2) test to compare the goodness of fit of observed phenotypic ratios with expected ratios.	**AT h** Students could investigate genetic ratios using crosses of *Drosophila* or Fast Plant® **MS 0.3** Students could use information to represent phenotypic ratios in monohybrid and dihybrid crosses. **MS 1.4** Students could show understanding of the probability associated with inheritance. **MS 1.9** Students could use the X^2 test to investigate the significance of differences between expected and observed phenotypic ratios.

3.7.2 Populations (A-level only)

Content	Opportunities for skills development
Species exist as one or more populations. A population as a group of organisms of the same species occupying a particular space at a particular time that can potentially interbreed. The concepts of gene pool and allele frequency. The Hardy–Weinberg principle provides a mathematical model, which predicts that allele frequencies will not change from generation to generation. The conditions under which the principle applies. The frequency of alleles, genotypes and phenotypes in a population can be calculated using the Hardy–Weinberg equation: $p^2 + 2pq + q^2 = 1$ where p is the frequency of one (usually the dominant) allele and q is the frequency of the other (usually recessive) allele of the gene.	**AT k** Students could collect data about the frequency of observable phenotypes within a single population. **MS 2.4** Students could calculate allele, genotype and phenotype frequencies from appropriate data using the Hardy–Weinberg equation.

3.7.3 Evolution may lead to speciation (A-level only)

Content	Opportunities for skills development
Individuals within a population of a species may show a wide range of variation in phenotype. This is due to genetic and environmental factors. The primary source of genetic variation is mutation. Meiosis and the random fertilisation of gametes during sexual reproduction produce further genetic variation. Predation, disease and competition for the means of survival result in differential survival and reproduction, ie natural selection. Those organisms with phenotypes providing selective advantages are likely to produce more offspring and pass on their favourable alleles to the next generation. The effect of this differential reproductive success on the allele frequencies within a gene pool. The effects of stabilising, directional and disruptive selection. Evolution as a change in the allele frequencies in a population. Reproductive separation of two populations can result in the accumulation of difference in their gene pools. New species arise when these genetic differences lead to an inability of members of the populations to interbreed and produce fertile offspring. In this way, new species arise from existing species. Allopatric and sympatric speciation.The importance of genetic drift in causing changes in allele frequency in small populations. **Students should be able to:** • explain why individuals within a population of a species may show a wide range of variation in phenotype • explain why genetic drift is important only in small populations • explain how natural selection and isolation may result in change in the allele and phenotype frequency and lead to the formation of a new species • explain how evolutionary change over a long period of time has resulted in a great diversity of species.	**MS 1.5** Students could apply their knowledge of sampling to the concept of genetic drift. **PS 1.2** Students could devise an investigation to mimic the effects of random sampling on allele frequencies in a population. **AT I** Students could use computer programs to model the effects of natural selection and of genetic drift.

3.7.4 Populations in ecosystems (A-level only)

<table>
<tr><th>Content</th><th>Opportunities for skills development</th></tr>
<tr><td>
Populations of different species form a community. A community and the non-living components of its environment together form an ecosystem. Ecosystems can range in size from the very small to the very large.
Within a habitat, a species occupies a niche governed by adaptation to both abiotic and biotic conditions.
An ecosystem supports a certain size of population of a species, called the carrying capacity. This population size can vary as a result of:

the effect of abiotic factors
interactions between organisms: interspecific and intraspecific competition and predation.

The size of a population can be estimated using:

randomly placed quadrats, or quadrats along a belt transect, for slow-moving or non-motile organisms
the mark-release-recapture method for motile organisms. The assumptions made when using the mark-release-recapture method.

Ecosystems are dynamic systems.
Primary succession, from colonisation by pioneer species to climax community.
At each stage in succession, certain species may be recognised which change the environment so that it becomes more suitable for other species with different adaptations. The new species may change the environment in such a way that it becomes less suitable for the previous species.
Changes that organisms produce in their abiotic environment can result in a less hostile environment and change biodiversity.
Conservation of habitats frequently involves management of succession.
Students should be able to:

show understanding of the need to manage the conflict between human needs and conservation in order to maintain the sustainability of natural resources
evaluate evidence and data concerning issues relating to the conservation of species and habitats and consider conflicting evidence
use given data to calculate the size of a population estimated using the mark-release-recapture method.

</td><td>
AT k
Students could:

investigate the distribution of organisms in a named habitat using randomly placed frame quadrats, or a belt transect
use both percentage cover and frequency as measures of abundance of a sessile species.

AT h
Students could use the mark-release-recapture method to investigate the abundance of a motile species.
AT i
Students could use turbidity measurements to investigate the growth rate of a broth culture of microorganisms.
MS 2.5
Students could use a logarithmic scale in representing the growth of a population of microorganisms.
</td></tr>
<tr><td>Required practical 12: Investigation into the effect of a named environmental factor on the distribution of a given species.</td><td>AT a and k</td></tr>
</table>

3.8 The control of gene expression (A-level only)

Cells are able to control their metabolic activities by regulating the transcription and translation of their genome. Although the cells within an organism carry the same genetic code, they translate only part of it. In multicellular organisms, this control of translation enables cells to have specialised functions, forming tissues and organs.

There are many factors that control the expression of genes and, thus, the phenotype of organisms. Some are external, environmental factors, others are internal factors. The expression of genes is not as simple as once thought, with epigenetic regulation of transcription being increasingly recognised as important.

Humans are learning how to control the expression of genes by altering the epigenome, and how to alter genomes and proteomes of organisms. This has many medical and technological applications.

Consideration of cellular control mechanisms underpins the content of this section. Students who have studied it should develop an understanding of the ways in which organisms and cells control their activities. This should lead to an appreciation of common ailments resulting from a breakdown of these control mechanisms and the use of DNA technology in the diagnosis and treatment of human diseases.

3.8.1 Alteration of the sequence of bases in DNA can alter the structure of proteins (A-level only)

Content	Opportunities for skills development
Gene mutations might arise during DNA replication. They include addition, deletion, substitution, inversion, duplication and translocation of bases. Gene mutations occur spontaneously. The mutation rate is increased by mutagenic agents. Mutations can result in a different amino acid sequence in the encoded polypeptide. • Some gene mutations change only one triplet code. Due to the degenerate nature of the genetic code, not all such mutations result in a change to the encoded amino acid. • Some gene mutations change the nature of all base triplets downstream from the mutation, ie result in a frame shift. **Students should be able to** relate the nature of a gene mutation to its effect on the encoded polypeptide.	

3.8.2 Gene expression is controlled by a number of features (A-level only)

3.8.2.1 Most of a cell's DNA is not translated (A-level only)

Content	Opportunities for skills development
Totipotent cells are cells that can mature into any type of body cell. During development, totipotent cells translate only part of their DNA, resulting in cell specialisation. Totipotent cells occur only for a limited time in mammalian embryos. Pluripotent, multipotent and unipotent cells are found in mature mammals. They can divide to form a limited number of different cell types. • Pluripotent stem cells can divide in unlimited numbers and can be used in treating human disorders. • Unipotent cells, exemplified by cardiomycetes. • Induced pluripotent stem cells (iPS cells) can be produced from unipotent cells using appropriate protein transcription factors. **Students should be able to** evaluate the use of stem cells in treating human disorders.	**AT i** Students could produce tissue cultures of explants of cauliflower (*Brassica oleracea*).

3.8.2.2 Regulation of transcription and translation (A-level only)

Content	Opportunities for skills development
In eukaryotes, transcription of target genes can be stimulated or inhibited when specific transcriptional factors move from the cytoplasm into the nucleus. The role of the steroid hormone, oestrogen, in initiating transcription. Epigenetic control of gene expression in eukaryotes. Epigenetics involves heritable changes in gene function, without changes to the base sequence of DNA. These changes are caused by changes in the environment that inhibit transcription by: • increased methylation of the DNA or • decreased acetylation of associated histones. The relevance of epigenetics on the development and treatment of disease, especially cancer. In eukaryotes and some prokaryotes, translation of the mRNA produced from target genes can be inhibited by RNA interference (RNAi). **Students should be able to**: • interpret data provided from investigations into gene expression • evaluate appropriate data for the relative influences of genetic and environmental factors on phenotype.	

3.8.2.3 Gene expression and cancer (A-level only)

Content	Opportunities for skills development
The main characteristics of benign and malignant tumours. The role of the following in the development of tumours: • tumour suppressor genes and oncogenes • abnormal methylation of tumour suppressor genes and oncogenes • increased oestrogen concentrations in the development of some breast cancers. **Students should be able to:** • evaluate evidence showing correlations between genetic and environmental factors and various forms of cancer • interpret information relating to the way in which an understanding of the roles of oncogenes and tumour suppressor genes could be used in the prevention, treatment and cure of cancer.	

3.8.3 Using genome projects (A-level only)

Content	Opportunities for skills development
Sequencing projects have read the genomes of a wide range of organisms, including humans. Determining the genome of simpler organisms allows the sequences of the proteins that derive from the genetic code (the proteome) of the organism to be determined. This may have many applications, including the identification of potential antigens for use in vaccine production. In more complex organisms, the presence of non-coding DNA and of regulatory genes means that knowledge of the genome cannot easily be translated into the proteome. Sequencing methods are continuously updated and have become automated.	

3.8.4 Gene technologies allow the study and alteration of gene function allowing a better understanding of organism function and the design of new industrial and medical processes (A-level only)

3.8.4.1 Recombinant DNA technology (A-level only)

Content	Opportunities for skills development
Recombinant DNA technology involves the transfer of fragments of DNA from one organism, or species, to another. Since the genetic code is universal, as are transcription and translation mechanisms, the transferred DNA can be translated within cells of the recipient (transgenic) organism. Fragments of DNA can be produced by several methods, including: • conversion of mRNA to complementary DNA (cDNA), using reverse transcriptase • using restriction enzymes to cut a fragment containing the desired gene from DNA • creating the gene in a 'gene machine'. Fragments of DNA can be amplified by *in vitro* and *in vivo* techniques. The principles of the polymerase chain reaction (PCR) as an *in vitro* method to amplify DNA fragments. The culture of transformed host cells as an *in vivo* method to amplify DNA fragments. • The addition of promoter and terminator regions to the fragments of DNA. • The use of restriction endonucleases and ligases to insert fragments of DNA into vectors. Transformation of host cells using these vectors. • The use of marker genes to detect genetically modified (GM) cells or organisms. (Students will **not** be required to recall specific marker genes in a written paper.) **Students should be able to:** • interpret information relating to the use of recombinant DNA technology • evaluate the ethical, financial and social issues associated with the use and ownership of recombinant DNA technology in agriculture, in industry and in medicine • balance the humanitarian aspects of recombinant DNA technology with the opposition from environmentalists and anti-globalisation activists • relate recombinant DNA technology to gene therapy.	**AT g** Students could investigate the specificity of restriction enzymes using extracted DNA and electrophoresis.

3.8.4.2 Differences in DNA between individuals of the same species can be exploited for identification and diagnosis of heritable conditions (A-level only)

Content	Opportunities for skills development
The use of labelled DNA probes and DNA hybridisation to locate specific alleles of genes. The use of labelled DNA probes that can be used to screen patients for heritable conditions, drug responses or health risks. The use of this information in genetic counselling and personalised medicine. **Students should be able to** evaluate information relating to screening individuals for genetically determined conditions and drug responses.	

3.8.4.3 Genetic fingerprinting (A-level only)

Content	Opportunities for skills development
An organism's genome contains many variable number tandem repeats (VNTRs). The probability of two individuals having the same VNTRs is very low. The technique of genetic fingerprinting in analysing DNA fragments that have been cloned by PCR, and its use in determining genetic relationships and in determining the genetic variability within a population. The use of genetic fingerprinting in the fields of forensic science, medical diagnosis, animal and plant breeding. **Students should be able to:** • explain the biological principles that underpin genetic fingerprinting techniques • interpret data showing the results of gel electrophoresis to separate DNA fragments • explain why scientists might use genetic fingerprinting in the fields of forensic science, medical diagnosis, animal and plant breeding.	**AT g** Students could use gel electrophoresis to produce 'fingerprints' of food dyes.

4 Scheme of assessment

Find past papers and mark schemes, and specimen papers for new courses, on our website at aqa.org.uk/pastpapers

The AS specification is designed to be taken over one or two years with all assessments taken at the end of the course. The A-level specification is designed to be taken over two years with all assessments taken at the end of the course.

Assessments and certification for the AS specification are available for the first time in May/June 2016 and then every May/June for the life of the specification.

Assessments and certification for the A-level specification are available for the first time in May/June 2017 and then every May/June for the life of the specification.

These are linear qualifications. In order to achieve the award, students must complete all exams in May/June in a single year. All assessments must be taken in the same series.

Questions for these specifications will be set which require students to demonstrate:

- their knowledge and understanding of the content developed in one section or topic, including the associated mathematical and practical skills or
- the ability to apply mathematical and practical skills to areas of content they are not normally developed in or
- the ability to draw together different areas of knowledge and understanding within one answer.

A range of question types will be used, including those that require extended responses. Extended response questions will allow students to demonstrate their ability to construct and develop a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. Extended responses may be in written English, extended calculations, or a combination of both, as appropriate to the question.

All materials are available in English only.

4.1 Aims

Courses based on these specifications should encourage students 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.

4.2 Assessment objectives

Assessment objectives (AOs) are set by Ofqual and are the same across all AS and A-level Biology specifications and all exam boards.

The exams will measure how students have achieved the following assessment objectives.

- 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.

Weighting of assessment objectives for AS Biology

Assessment objectives (AOs)	Component weightings (approx %)		Overall weighting (approx %)
	Paper 1	Paper 2	
AO1	47–51	33–37	35–40
AO2	35–39	41–45	40–45
AO3	13–17	21–25	20–25
Overall weighting of components	50	50	100

10% of the overall assessment of AS Biology will contain mathematical skills equivalent to Level 2 or above.

At least 15% of the overall assessment of AS Biology will assess knowledge, skills and understanding in relation to practical work.

Weighting of assessment objectives for A-level Biology

Assessment objectives (AOs)	Component weightings (approx %)			Overall weighting (approx %)
	Paper 1	Paper 2	Paper 3	
AO1	44–48	23–27	28–32	30–35
AO2	30–34	52–56	35–39	40–45
AO3	20–24	19–23	31–35	25–30
Overall weighting of components	35	35	30	100

10% of the overall assessment of A-level Biology will contain mathematical skills equivalent to Level 2 or above.

At least 15% of the overall assessment of A-level Biology will assess knowledge, skills and understanding in relation to practical work.

4.3 Assessment weightings

The marks awarded on the papers will be scaled to meet the weighting of the components. Students' final marks will be calculated by adding together the scaled marks for each component. Grade boundaries will be set using this total scaled mark. The scaling and total scaled marks are shown in the table below.

AS

Component	Maximum raw mark	Scaling factor	Maximum scaled mark
Paper 1	75	x1	75
Paper 2	75	x1	75
		Total scaled mark:	150

A-level

Component	Maximum raw mark	Scaling factor	Maximum scaled mark
Paper 1	91	x1	91
Paper 2	91	x1	91
Paper 3	78	x1	78
		Total scaled mark:	260

5 General administration

You can find information about all aspects of administration, as well as all the forms you need, at aqa.org.uk/examsadmin

5.1 Entries and codes

You only need to make one entry for each qualification.

Every specification is given a national discount (classification) code by the Department for Education (DfE), which indicates its subject area.

If a student takes two specifications with the same discount code, Further and Higher Education providers are likely to take the view that they have only achieved one of the two qualifications. Please check this before your students start their course.

Qualification title	AQA entry code	DfE discount code
AQA Advanced Subsidiary GCE in Biology	7401	1010 (post-16), RH3 (KS4)
AQA Advanced Level GCE in Biology	7402	1010

These specifications comply with Ofqual's:

- *General conditions of recognition* that apply to all regulated qualifications
- GCE qualification level conditions that apply to all GCEs
- GCE subject level conditions that apply to all GCEs in this subject
- all relevant regulatory documents.

Ofqual has accredited these specifications. The qualification accreditation number (QAN) for the AS is 601/4624/2. The QAN for the A-level is 601/4625/4.

5.2 Overlaps with other qualifications

There is overlapping content in the AS and A-level Biology specifications. This helps you teach the AS and A-level together.

5.3 Awarding grades and reporting results

The AS qualification will be graded on a five-point scale: A, B, C, D and E.

The A-level qualification will be graded on a six-point scale: A*, A, B, C, D and E.

Students who fail to reach the minimum standard for grade E will be recorded as U (unclassified) and will not receive a qualification certificate.

5.4 Re-sits and shelf life

Students can re-sit the qualifications as many times as they wish, within the shelf life of the qualifications.

5.5 Previous learning and prerequisites

There are no previous learning requirements. Any requirements for entry to a course based on these specifications are at the discretion of schools and colleges.

However, we recommend that students should have the skills and knowledge associated with at least GCSE Science and Additional Science or GCSE Biology (or equivalent qualifications).

5.6 Access to assessment: diversity and inclusion

General qualifications are designed to prepare students for a wide range of occupations and further study. Therefore our qualifications must assess a wide range of competences.

The subject criteria have been assessed to see if any of the skills or knowledge required present any possible difficulty to any students, whatever their ethnic background, religion, sex, age, disability or sexuality. If any difficulties were encountered, the criteria were reviewed again to make sure that tests of specific competences were only included if they were important to the subject.

As members of the Joint Council for Qualifications (JCQ) we participate in the production of the JCQ document *Access Arrangements and Reasonable Adjustments: General and Vocational qualifications*. We follow these guidelines when assessing the needs of individual students who may require an access arrangement or reasonable adjustment. This document is published on the JCQ website at jcq.org.uk

Students with disabilities and special needs

We can make arrangements for disabled students and students with special needs to help them access the assessments, as long as the competences being tested are not changed. Access arrangements must be agreed **before** the assessment. For example, a Braille paper would be a reasonable adjustment for a Braille reader but not for a student who does not read Braille.

We are required by the Equality Act 2010 to make reasonable adjustments to remove or lessen any disadvantage that affects a disabled student.

If you have students who need access arrangements or reasonable adjustments, you can apply using the Access arrangements online service at aqa.org.uk/eaqa

Special consideration

We can give special consideration to students who have been disadvantaged at the time of the assessment through no fault of their own – for example a temporary illness, injury or serious problem such as the death of a relative. We can only do this **after** the assessment.

Your exams officer should apply online for special consideration at aqa.org.uk/eaqa

For more information and advice about access arrangements, reasonable adjustments and special consideration please see aqa.org.uk/access or email accessarrangementsqueries@aqa.org.uk

5.7 Working with AQA for the first time

If your school or college has not previously offered any AQA specification, you need to register as an AQA centre to offer our specifications to your students. Find out how at aqa.org.uk/becomeacentre

If your school or college is new to these specifications, please let us know by completing an Intention to enter form. The easiest way to do this is via e-AQA at aqa.org.uk/eaqa

5.8 Private candidates

A private candidate is someone who enters for exams through an AQA-approved school or college but is not enrolled as a student there.

If you are a private candidate you may be self-taught, home-schooled or have private tuition, either with a tutor or through a distance learning organisation. You must be based in the UK.

If you have any queries as a private candidate, you can:

- speak to the exams officer at the school or college where you intend to take your exams
- visit our website at aqa.org.uk/examsadmin
- email: privatecandidates@aqa.org.uk

6 Mathematical requirements and exemplifications

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

Overall, at least 10% of the marks in assessments for biology will require the use of mathematical skills. These skills will be applied in the context of biology and will be at least the standard of higher tier GCSE mathematics.

The following tables illustrate where these mathematical skills may be developed during teaching or could be assessed. Those shown in **bold type** would only be tested in the full A-level course.

This list of examples is not exhaustive. These skills could be developed or assessed in other areas of specification content. Other areas where these skills could be developed have been exemplified throughout these specifications.

6.1 Arithmetic and numerical computation

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 0.1	Recognise and make use of appropriate units in calculations	Students may be tested on their ability to: • convert between units, eg mm3 to cm3 as part of volumetric calculations • work out the unit for a rate, eg breathing rate
MS 0.2	Recognise and use expressions in decimal and standard form	Students may be tested on their ability to: • use an appropriate number of decimal places in calculations, eg for a mean • carry out calculations using numbers in standard and ordinary form, eg 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, eg 0.0050 mol dm–3 is equivalent to 5.0 × 10–3 mol dm–3

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 0.3	Use ratios, fractions and percentages	Students 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)
MS 0.4	Estimate results	Students may be tested on their ability to: • estimate results to sense check that the calculated values are appropriate
MS 0.5	**Use calculators to find and use power, exponential and logarithmic functions**	**Students may be tested on their ability to:** • **estimate the number of bacteria grown over a certain length of time**

6.2 Handling data

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 1.1	Use an appropriate number of significant figures	Students 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
MS 1.2	Find arithmetic means	Students may be tested on their ability to: • find the mean of a range of data, eg the mean number of stomata in the leaves of a plant
MS 1.3	Construct and interpret frequency tables and diagrams, bar charts and histograms	Students 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, eg data relating to organ function • plot a range of data in an appropriate format, eg enzyme activity over time represented on a graph • interpret data for a variety of graphs, eg explain electrocardiogram traces
MS 1.4	Understand simple probability	Students may be tested on their ability to: • use the terms probability and chance appropriately • understand the probability associated with genetic inheritance

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 1.5	Understand the principles of sampling as applied to scientific data	Students may be tested on their ability to: • analyse random data collected by an appropriate means, eg use Simpson's index of diversity to calculate the biodiversity of a habitat
MS 1.6	Understand the terms mean, median and mode	Students may be tested on their ability to: • calculate or compare the mean, median and mode of a set of data, eg height/mass/size of a group of organisms
MS 1.7	Use a scatter diagram to identify a correlation between two variables	Students may be tested on their ability to: • interpret a scattergram, eg the effect of lifestyle factors on health
MS 1.8	Make order of magnitude calculations	Students may be tested on their ability to: • use and manipulate the magnification formula $\text{magnification} = \frac{\text{size of image}}{\text{size of real object}}$
MS 1.9	Select and use a statistical test	Students may be tested on their ability to select and use: • the chi-squared test to test the significance of the difference between observed and expected results • the Student's t-test • the correlation coefficient
MS 1.10	Understand measures of dispersion, including standard deviation and range	Students 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, eg where there is an outlying result
MS 1.11	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	Students may be tested on their ability to: • calculate percentage error where there are uncertainties in measurement

6.3 Algebra

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 2.1	Understand and use the symbols: =, <, <<, >>, >, ∝, ~.	No exemplification required.
MS 2.2	Change the subject of an equation	Students may be tested on their ability to: • use and manipulate equations, eg magnification
MS 2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Students may be tested on their ability to: • use a given equation, eg Simpson's index of diversity $d = \frac{N(N-1)}{\Sigma n(n-1)}$
MS 2.4	Solve algebraic equations	Students may be tested on their ability to: • solve equations in a biological context, eg $cardiac\ output = stroke\ volume \times heart\ rate$
MS 2.5	**Use logarithms in relation to quantities that range over several orders of magnitude**	**Students may be tested on their ability to:** • **use a logarithmic scale in the context of microbiology, eg growth rate of a microorganism such as yeast**

6.4 Graphs

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 3.1	Translate information between graphical, numerical and algebraic forms	Students 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, eg dissociation curves
MS 3.2	Plot two variables from experimental or other data	Students may be tested on their ability to: • select an appropriate format for presenting data, bar charts, histograms, graphs and scattergrams
MS 3.3	Understand that $y = mx + c$ represents a linear relationship	Students may be tested on their ability to: • predict/sketch the shape of a graph with a linear relationship, eg the effect of substrate concentration on the rate of an enzyme-controlled reaction with excess enzyme
MS 3.4	**Determine the intercept of a graph**	**Students may be tested on their ability to:** • **read off an intercept point from a graph, eg compensation point in plants**
MS 3.5	Calculate rate of change from a graph showing a linear relationship	Students may be tested on their ability to: • calculate a rate from a graph, eg rate of transpiration
MS 3.6	Draw and use the slope of a tangent to a curve as a measure of rate of change	Students may be tested on their ability to: • use this method to measure the gradient of a point on a curve, eg amount of product formed plotted against time when the concentration of enzyme is fixed

6.5 Geometry and trigonometry

	Mathematical skills	Exemplification of mathematical skill in the context of Biology
MS 4.1	Calculate the circumferences, surface areas and volumes of regular shapes	Students 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 • eg calculate the surface area or volume of a cell

7 AS practical assessment

Practical work is at the heart of biology, so we have placed it at the heart of this specification.

Assessment of practical skills in this AS specification will be by written exams only.

The practical endorsement does not apply to the AS specification. A rich diet of practical work is essential to develop students' manipulative skills and understanding of the processes of scientific investigation. It also contributes to teaching and learning of the concepts within this specification.

Questions in the papers have been written in the expectation that students have carried out at least the six required practical activities in section 7.2.

15% of the marks in the papers will relate to practical work.

7.1. Use of apparatus and techniques

All students taking this specification are expected to have carried out the required practical activities in section 7.2. These develop skills in the use of many of the following apparatus and techniques. This list is a compulsory element of the full A-level course. It is reproduced here for reference and to aid co-teaching the AS and A-level specifications.

	Apparatus and techniques
AT a	use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)
AT b	use appropriate instrumentation to record quantitative measurements, such as a colorimeter or potometer
AT c	use laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions
AT d	use of light microscope at high power and low power, including use of a graticule
AT e	produce scientific drawing from observation with annotations
AT f	use qualitative reagents to identify biological molecules
AT g	separate biological compounds using thin layer/paper chromatography or electrophoresis
AT h	safely and ethically use organisms to measure: • plant or animal responses • physiological functions
AT i	use microbiological aseptic techniques, including the use of agar plates and broth
AT j	safely use instruments for dissection of an animal organ, or plant organ
AT k	use sampling techniques in fieldwork
AT l	use ICT such as computer modelling, or data logger to collect data, or use software to process data

7.2 AS required practical activities

The following practicals must be carried out by all students taking this course. Written papers will assess knowledge and understanding of these, and the skills exemplified within each practical.

Required activity	Apparatus and technique reference
1. Investigation into the effect of a named variable on the rate of an enzyme-controlled reaction	a, b, c, f, l
2. Preparation of stained squashes of cells from plant root tips; set-up and use of an optical microscope to identify the stages of mitosis in these stained squashes and calculation of a mitotic index	d, e, f
3. Production of a dilution series of a solute to produce a calibration curve with which to identify the water potential of plant tissue	c, h, j, l
4. Investigation into the effect of a named variable on the permeability of cell-surface membranes	a, b, c, j, l
5. Dissection of animal or plant gas exchange system or mass transport system or of organ within such a system	e, h, j
6. Use of aseptic techniques to investigate the effect of antimicrobial substances on microbial growth	c, i

Teachers are encouraged to vary their approach to these practical activities. Some are more suitable for highly structured approaches that develop key techniques. Others allow opportunities for students to develop investigative approaches.

This list is not designed to limit the practical activities carried out by students. A rich practical experience for students will include more than the six required practical activities. The explicit teaching of practical skills will build students' competence. Many teachers will also use practical approaches to the introduction of content knowledge in the course of their normal teaching.

7.3 Practical skills to be assessed in written papers

Overall, at least 15% of the marks for an AS Biology qualification will require the assessment of practical skills.

In order to be able to answer these questions, students need to have been taught, and to have acquired competence in, the appropriate areas of practical skills as indicated in the table of coverage below.

7.3.1 Independent thinking

	Practical skill
PS 1.1	Solve problems set in practical contexts
PS 1.2	Apply scientific knowledge to practical contexts

7.3.2 Use and application of scientific methods and practices

	Practical skill
PS 2.1	Comment on experimental design and evaluate scientific methods
PS 2.2	Present data in appropriate ways
PS 2.3	Evaluate results and draw conclusions with reference to measurement uncertainties and errors
PS 2.4	Identify variables including those that must be controlled

7.3.3 Numeracy and the application of mathematical concepts in a practical context

	Practical skill
PS 3.1	Plot and interpret graphs
PS 3.2	Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science
PS 3.3	Consider margins of error, accuracy and precision of data

7.3.4 Instruments and equipment

	Practical skill
PS 4.1	Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification

8 A-level practical assessment

Practical work is at the heart of biology, so we have placed it at the heart of this specification.

Practical assessments have been divided into those that can be assessed in written exams and those that can only be directly assessed whilst students are carrying out experiments.

A-level grades will be based only on marks from written exams.

A separate endorsement of practical skills will be taken alongside the A-level. This will be assessed by teachers and will be based on direct observation of students' competency in a range of skills that are not assessable in written exams.

8.1 Use of apparatus and techniques

All students taking an A-level Biology qualification are expected to have had opportunities to use the following apparatus and develop and demonstrate these techniques. These apparatus and techniques are common to all A-level Biology specifications.

Carrying out the 12 required practicals in section 8.2 means that students will have experienced use of each of these apparatus and techniques. However, teachers are encouraged to develop students' abilities by inclusion of other opportunities for skills development, as exemplified in the right-hand column of the content section of this specification.

	Apparatus and techniques
AT a	use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)
AT b	use appropriate instrumentation to record quantitative measurements, such as a colorimeter or potometer
AT c	use laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions
AT d	use of light microscope at high power and low power, including use of a graticule
AT e	produce scientific drawing from observation with annotations
AT f	use qualitative reagents to identify biological molecules
AT g	separate biological compounds using thin layer/paper chromatography or electrophoresis
AT h	safely and ethically use organisms to measure: • plant or animal responses • physiological functions
AT i	use microbiological aseptic techniques, including the use of agar plates and broth
AT j	safely use instruments for dissection of an animal organ, or plant organ
AT k	use sampling techniques in fieldwork
AT l	use ICT such as computer modelling, or data logger to collect data, or use software to process data

8.2 A-level required practical activities

The following practicals must be carried out by all students taking this course. Written papers will assess knowledge and understanding of these, and the skills exemplified within each practical.

Required activity	Apparatus and technique reference
1. Investigation into the effect of a named variable on the rate of an enzyme-controlled reaction	a, b, c, f, l
2. Preparation of stained squashes of cells from plant root tips; set-up and use of an optical microscope to identify the stages of mitosis in these stained squashes and calculation of a mitotic index	d, e, f
3. Production of a dilution series of a solute to produce a calibration curve with which to identify the water potential of plant tissue	c, h, j, l
4. Investigation into the effect of a named variable on the permeability of cell-surface membranes	a, b, c, j, l
5. Dissection of animal or plant gas exchange or mass transport system or of organ within such a system	e, h, j
6. Use of aseptic techniques to investigate the effect of antimicrobial substances on microbial growth	c, i
7. Use of chromatography to investigate the pigments isolated from leaves of different plants, eg leaves from shade-tolerant and shade-intolerant plants or leaves of different colours	b, c, g
8. Investigation into the effect of a named factor on the rate of dehydrogenase activity in extracts of chloroplasts	a, b, c
9. Investigation into the effect of a named variable on the rate of respiration of cultures of single-celled organisms	a, b, c, i
10. Investigation into the effect of an environmental variable on the movement of an animal using either a choice chamber or a maze	h
11. Production of a dilution series of a glucose solution and use of colorimetric techniques to produce a calibration curve with which to identify the concentration of glucose in an unknown 'urine' sample	b, c, f
12. Investigation into the effect of a named environmental factor on the distribution of a given species	a, b, h, k, l

Teachers are encouraged to vary their approach to these practical activities. Some are more suitable for highly structured approaches that develop key techniques. Others allow opportunities for students to develop investigative approaches.

This list is not designed to limit the practical activities carried out by students. A rich practical experience for students will include more than the 12 required practical activities. The explicit teaching of practical skills will build students' competence. Many teachers will also use practical approaches to the introduction of content knowledge in the course of their normal teaching. Students' work in these activities can also contribute towards the endorsement of practical skills.

8.3 Practical skills to be assessed in written papers

Overall, at least 15% of the marks for an A-level Biology qualification will require the assessment of practical skills.

In order to be able to answer these questions, students need to have been taught, and to have acquired competence in, the appropriate areas of practical skills as indicated in the table of coverage below.

8.3.1 Independent thinking

	Practical skill
PS 1.1	Solve problems set in practical contexts
PS 1.2	Apply scientific knowledge to practical contexts

8.3.2 Use and application of scientific methods and practices

	Practical skill
PS 2.1	Comment on experimental design and evaluate scientific methods
PS 2.2	Present data in appropriate ways
PS 2.3	Evaluate results and draw conclusions with reference to measurement uncertainties and errors
PS 2.4	Identify variables including those that must be controlled

8.3.3 Numeracy and the application of mathematical concepts in a practical context

	Practical skill
PS 3.1	Plot and interpret graphs
PS 3.2	Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science
PS 3.3	Consider margins of error, accuracy and precision of data

8.3.4 Instruments and equipment

	Practical skill
PS 4.1	Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification

8.4 A-level practical skills to be assessed via endorsement

8.4.1 Cross-board statement on practical endorsement

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) and 5c (Use of apparatus and techniques) from the prescribed subject content, published by the Department for Education. The required practical activities will be defined by each awarding organisation.
- Teachers will assess students against Common Practical Assessment Criteria (CPAC) issued by the awarding organisations. The draft CPAC (see below) 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) 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.

8.4.2 Draft criteria for the assessment of practical competency in A-level Biology, Chemistry and Physics

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 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 of the DfE content for sciences, 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.

Competency	Practical mastery
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.

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