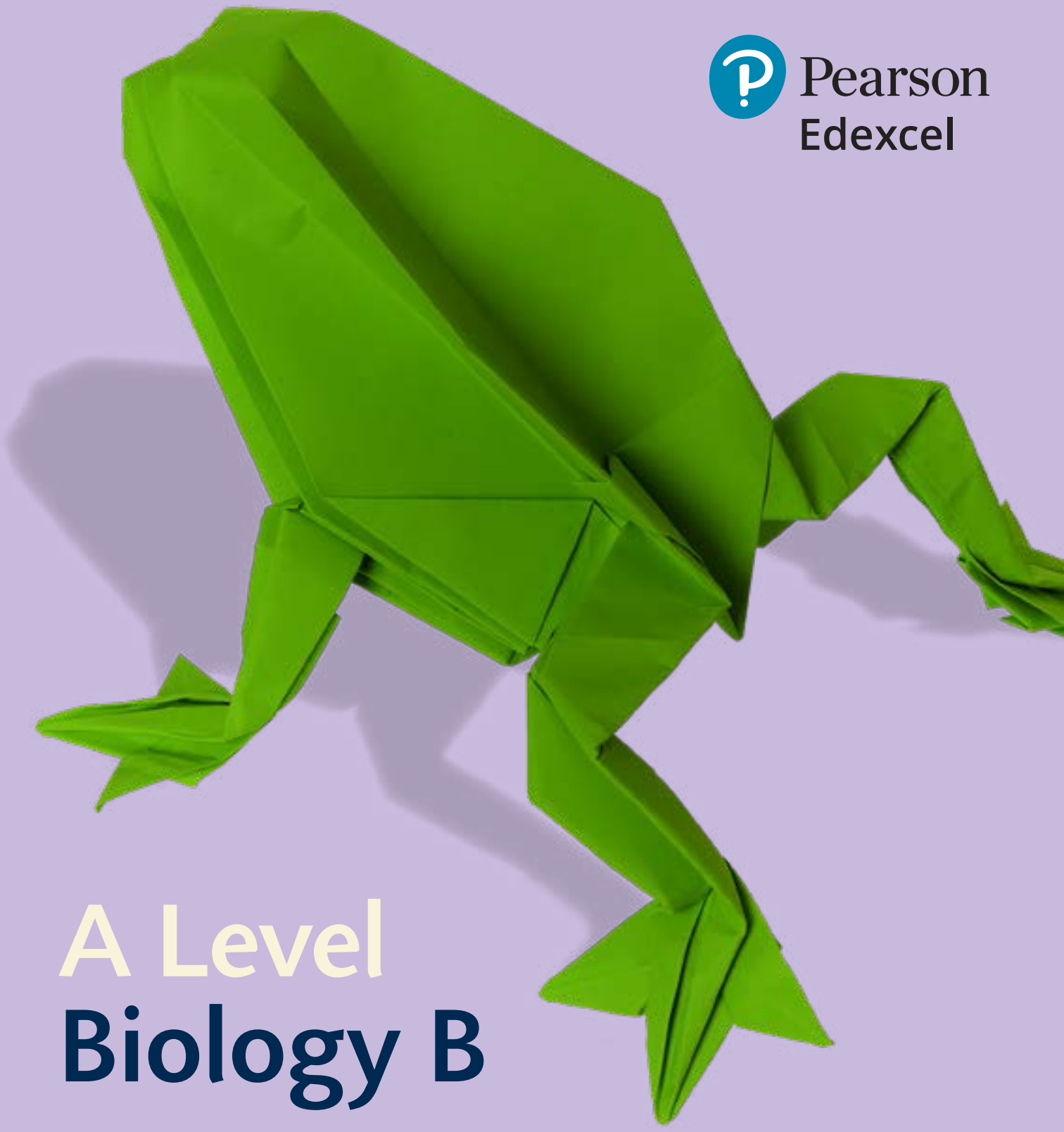

Pearson Edexcel

A Level Biology B

Specification

Pearson Edexcel Level 3 Advanced GCE in Biology B (9BI0)

First teaching from September 2015

First certification from 2017

Issue 4

Pearson Edexcel Level 3 Advanced GCE in Biology B (9BI0)

Specification

First certification 2017

Issue 4

Edexcel, BTEC and LCCI qualifications

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All information in this specification is correct at time of publication.

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From Pearson's Expert Panel for World Class Qualifications

May 2014

"The reform of the qualifications system in England is a profoundly important change to the education system. Teachers need to know that the new qualifications will assist them in helping their learners make progress in their lives.

When these changes were first proposed we were approached by Pearson to join an 'Expert Panel' that would advise them on the development of the new qualifications.

We were chosen, either because of our expertise in the UK education system, or because of our experience in reforming qualifications in other systems around the world as diverse as Singapore, Hong Kong, Australia and a number of countries across Europe.

We have guided Pearson through what we judge to be a rigorous qualification development process that has included:

- extensive international comparability of subject content against the highest-performing jurisdictions in the world
- benchmarking assessments against UK and overseas providers to ensure that they are at the right level of demand
- establishing External Subject Advisory Groups, drawing on independent subject-specific expertise to challenge and validate our qualifications
- subjecting the final qualifications to scrutiny against the DfE content and Ofqual accreditation criteria in advance of submission.

Importantly, we have worked to ensure that the content and learning is future oriented. The design has been guided by what is called an 'Efficacy Framework', meaning learner outcomes have been at the heart of this development throughout.

We understand that ultimately it is excellent teaching that is the key factor to a learner's success in education. As a result of our work as a panel we are confident that we have supported the development of qualifications that are outstanding for their coherence, thoroughness and attention to detail and can be regarded as representing world-class best practice."

Sir Michael Barber (Chair)
Chief Education Advisor, Pearson plc

Bahram Bekhradnia
President, Higher Education Policy Institute

Dame Sally Coates
Principal, Burlington Danes Academy

Professor Robin Coningham
Pro-Vice Chancellor, University of Durham

Dr Peter Hill
Former Chief Executive ACARA

Professor Lee Sing Kong
Director, National Institute of Education, Singapore

Professor Jonathan Osborne
Stanford University

Professor Dr Ursula Renold
Federal Institute of Technology, Switzerland

Professor Bob Schwartz
Harvard Graduate School of Education

All titles correct as at May 2014

Introduction

The Pearson Edexcel Level 3 Advanced GCE in Biology B is designed for use in schools and colleges. It is part of a suite of GCE qualifications offered by Pearson.

Purpose of the specification

This specification sets out:

- the objectives of the qualification
- any other qualification(s) that a student must have completed before taking the qualification
- any prior knowledge and skills that the student is required to have before taking the qualification
- any other requirements that a student must have satisfied before they will be assessed or before the qualification will be awarded
- the knowledge and understanding that will be assessed as part of the qualification
- the method of assessment and any associated requirements relating to it
- the criteria against which a student's level of attainment will be measured (such as assessment criteria).

Rationale

The Pearson Edexcel Level 3 Advanced GCE in Biology B meets the following purposes, which fulfil those defined by the Office of Qualifications and Examinations Regulation (Ofqual) for GCE qualifications in their *GCE Qualification Level Conditions and Requirements* document, published in April 2014.

The purposes of this qualification are to:

- define and assess achievement of the knowledge, skills and understanding that will be needed by students planning to progress to undergraduate study at UK higher education institutions, particularly (although not only) in biology
- set out a robust and internationally comparable post-16 academic course of study to develop that knowledge, skills and understanding
- enable HE institutions to identify accurately the level of attainment of students
- provide a basis for school and college accountability measures at age 18
- provide a benchmark of academic ability for employers.

Qualification aims and objectives

The aims and objectives of the Pearson Edexcel Level 3 Advanced GCE in Biology B are to enable students to develop:

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

The context for the development of this qualification

All our qualifications are designed to meet our World Class Qualification Principles[1] and our ambition to put the student at the heart of everything we do.

We have developed and designed this qualification by:

- reviewing other curricula and qualifications to ensure that it is comparable with those taken in high-performing jurisdictions overseas
- consulting with key stakeholders on content and assessment, including subject associations, higher education academics, teachers and employers to ensure this qualification is suitable for a UK context
- reviewing the legacy qualification and building on its positive attributes.

This qualification has also been developed to meet criteria stipulated by Ofqual in their document *GCE Qualification Level Conditions and Requirements* and by the Department for Education (DfE) in their *GCE AS and A level regulatory requirements for biology, chemistry, physics and psychology* document, published in April 2014.

[1] Pearson's World Class Qualification principles ensure that our qualifications are:

- **demanding**, through internationally benchmarked standards, encouraging deep learning and measuring higher-order skills
- **rigorous**, through setting and maintaining standards over time, developing reliable and valid assessment tasks and processes, and generating confidence in end users of the knowledge, skills and competencies of certified students
- **inclusive**, through conceptualising learning as continuous, recognising that students develop at different rates and have different learning needs, and focusing on progression
- **empowering**, through promoting the development of transferable skills, see *Appendix 1*.

Summary of Pearson Edexcel Level 3 Advanced GCE in Biology B specification Issue 4 changes

Summary of changes made between previous issue and this current issue	Page number
'Subject to confirmation in spring 2015 following trialling' has been deleted.	37 and 38

If you need further information on these changes or what they mean, contact us via our website at: qualifications.pearson.com/en/support/contact-us.html.

Contents

Qualification at a glance

The Pearson Edexcel Level 3 Advanced GCE in Biology B consists of three externally examined papers and the Science Practical Endorsement.

Students are expected to carry out the 16 core practical experiments that are identified in the content.

Students must complete all assessment in May/June in any single year.

Paper 1: Advanced Biochemistry, Microbiology and Genetics ***Paper code: 9BI0/01**	
• Externally assessed • Availability: May/June • First assessment: 2017	**30% of the total qualification**
Overview of content This paper will examine the following topics: • Topic 1: Biological Molecules • Topic 2: Cells, Viruses and Reproduction of Living Things • Topic 3: Classification and Biodiversity • Topic 4: Exchange and Transport • Topic 5: Energy for Biological Processes • Topic 6: Microbiology and Pathogens • Topic 7: Modern Genetics.	
Overview of assessment • Assessment is 1 hour 45 minutes. • The paper consists of 90 marks. • The paper may include multiple-choice, short open, open-response, calculations and extended writing questions. • The paper will include questions that target mathematics at Level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*). Overall, a minimum of 10% of the marks across the three papers will be awarded for mathematics at Level 2 or above.	

Paper 2: Advanced Physiology, Evolution and Ecology ***Paper code: 9BI0/02**	
• Externally assessed • Availability: May/June • First assessment: 2017	**30% of the total qualification**
Overview of content This paper will examine the following topics: • Topic 1: Biological Molecules • Topic 2: Cells, Viruses and Reproduction of Living Things • Topic 3: Classification and Biodiversity • Topic 4: Exchange and Transport • Topic 8: Origins of Genetic Variation • Topic 9: Control Systems • Topic 10: Ecosystems.	
Overview of assessment • Assessment is 1 hour 45 minutes. • The paper consists of 90 marks. • The paper may include multiple-choice, short open, open-response, calculations and extended writing questions. • The paper will include questions that target mathematics at Level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*). Overall, a minimum of 10% of the marks across the three papers will be awarded for mathematics at Level 2 or above.	

Paper 3: General and Practical Principles in Biology ***Paper code: 9BI0/03**	
• Externally assessed • Availability: May/June • First assessment: 2017	**40% of the total qualification**
Overview of content • This paper will include questions from Topics 1–10.	
Overview of assessment • Assessment is 2 hours 30 minutes. • The paper consists of 120 marks. • The paper may include short open, open-response, calculations and extended writing questions. • The paper will include synoptic questions that may draw on two or more different topics. • The paper will include questions that target mathematics at Level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*). Overall, a minimum of 10% of the marks across the three papers will be awarded for mathematics at Level 2 or above. • The paper will include questions that target the conceptual and theoretical understanding of experimental methods.	

Science Practical Endorsement**

***Paper code: 9BI0/04**

- Internally assessed and externally monitored by Pearson.
- Availability: May/June
- First assessment: 2017

Overview of content

The assessment of practical skills is a compulsory requirement of the course of study for A level biology. It will appear on all students' certificates as a separately reported result, alongside the overall grade for the qualification.

Students must carry out a minimum of 12 practical activities 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.

The practical activities prescribed in this specification (the "core practicals") provide opportunities for demonstrating competence in all the skills identified, together with the use of apparatus and techniques for each subject. However, students can also demonstrate these competencies in any additional practical activity undertaken throughout the course of study which covers the requirements of *Appendix 5c.*

Overview of assessment

Students' practical work will be assessed by teachers, using common practical assessment criteria (CPAC) that are consistent across exam boards. These criteria can be found on pages 48-49.

Students who demonstrate the required standard across all the requirements of the CPAC will receive a 'pass' grade.

Students may work in groups but teachers who award a pass to their students need to be confident of individual students' competence.

The correct application of CPAC to students' work will be monitored through a system of visits to centres. These visits will be coordinated across the exam boards by JCQ, to ensure that all centres are visited regularly, although not necessarily in each science subject.

*See *Appendix 3: Codes* for a description of this code and all other codes relevant to this qualification.

** Students will be assessed separately for the Science Practical Endorsement. The Endorsement will not contribute to the overall grade for this qualification, but the result will be recorded on the student's certificate.

Knowledge, skills and understanding

Content overview

Students will be expected to demonstrate and apply the knowledge, understanding and skills described in the content for each topic below. In addition, they will be expected to analyse, interpret and evaluate a range of scientific information, ideas and evidence using their knowledge, understanding and skills.

To demonstrate knowledge, students should be able to undertake a range of activities, including the ability to recall, describe and define, as appropriate. To demonstrate understanding, students should be able to explain ideas and use their knowledge to apply, analyse, interpret and evaluate, as appropriate.

Each topic begins with an overview of the wider biological context designed to encourage an overarching approach to both the teaching and learning of the subject. As such, it will not be directly assessed.

There are opportunities for students to develop mathematical skills throughout the content. They are required to apply the skills to relevant biology contexts. In order to be able to develop their skills, knowledge and understanding in science, students need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject. These skills will be applied in the context of biology and will be developed throughout the course. All mathematical skills listed in *Appendix 6* must be assessed within the lifetime of the qualification.

Content that is common to the Pearson Edexcel Level 3 Advanced Subsidiary GCE in Biology B is in Topics 1-4.

Practical skills

Practical work is central to any study of biology. For this reason, the specification includes 16 core practical activities which form a thread linking theoretical knowledge and understanding to practical scenarios. In following this thread, students will build on practical skills learned at GCSE, becoming confident practical biologists, handling apparatus competently and safely. Using a variety of apparatus and techniques, they should be able to design and carry out both the core practical activities and their own investigations, collecting data which can be analysed and used to draw valid conclusions.

One important aspect of practical work is the ability to evaluate and manage potential risks. The variety of different practical techniques and scenarios in the core practical activities give students scope to consider risk management in different contexts.

Students should also consider the ethical issues presented by their work in the laboratory, which might include consideration for the ethical use of live subjects, the safe disposal of waste materials, and appropriate consideration for other people involved in their own work or who are working nearby.

Also central to the development of practical skills is the ability to communicate information and ideas through the use of appropriate terminology and ICT. Being able to communicate clearly the findings of practical work is arguably as important as the collection of accurate data.

In carrying out practical activities, students will be expected to use their knowledge and understanding to pose scientific questions which can be investigated through experimental activities. Such activities will enable students to collect data, analyse it for correlations and causal relationships, and to develop solutions to the questions posed.

Questions within written examination papers will aim to assess the knowledge and understanding that students gain while carrying out practical activities, within the context of the 16 core practical activities, as well as in novel practical scenarios. The written papers will test the skills of students in planning practical work – both in familiar and unfamiliar applications – including risk management and the selection of apparatus, with reasons. As part of data handling, students will be expected to use significant figures appropriately, to process data and to plot graphs. In analysing outcomes and drawing valid conclusions, students should critically consider methods and data, including assessing measurement uncertainties and errors.

Examination papers will also provide the opportunity for students to evaluate the wider role of the scientific community in validating new knowledge and the ways in which society as a whole uses science to inform decision making. Within this, they could be asked to consider the implications and applications of biology in terms of associated benefits and risks. Students may also be asked to evaluate methodology, evidence and data and resolve conflicting evidence.

Success in questions that indirectly assess practical skills within written papers will come more naturally to those candidates who have a solid foundation of laboratory practice and who, having carried them out, have a thorough understanding of practical techniques. Therefore, where possible, teachers should consider adding additional experiments to the core practical activities. The 16 core practicals will provide the basis from which some of the examination questions will be drawn.

Teachers should note that the completion of the 16 core practical activities can also provide evidence of competence for the Science Practical Endorsement (please see page 31) and that evidence must be provided for the 12 practical techniques listed in *Appendix 5c* through a minimum of 12 core practical activities.

Topic 1: Biological Molecules

This topic introduces the chemicals of life: the organic and inorganic molecules and ions that are fundamental to the structure and physiology of living organisms. The role of monomers in the synthesis of polymers and how the structure and properties of these relate to their functions are considered. An understanding of scientific method is developed in the practical investigation of enzyme action.

Opportunities for developing mathematical skills within this topic include: recognising and making use of appropriate units in calculations; using ratios, fractions and percentages; constructing and interpreting frequency tables and diagrams; translating information between graphical, numerical and algebraic forms; understanding that y = mx + c represents a linear relationship; determining the intercept of a graph; calculating rate of change from a graph; drawing and using the slope of a tangent to a curve as a measure of rate of change. (Please see *Appendix 6: Mathematical skills and exemplifications* for further information.)

Students should:	
1.1	**Carbohydrates**
i	Know the difference between monosaccharides, disaccharides and polysaccharides.
ii	Know the structure of the hexose glucose (alpha and beta) and the pentose ribose.
iii	Understand how monosaccharides (glucose, fructose, galactose) join to form disaccharides (sucrose, lactose and maltose) and polysaccharides (starch formed from amylose and amylopectin; glycogen) through condensation reactions forming glycosidic bonds, and how these can be split through hydrolysis reactions.
iv	Understand how the structure of glucose, starch, glycogen and cellulose relates to their function.
1.2	**Lipids**
i	Understand how a triglyceride is synthesised, including the formation of ester bonds during condensation reactions between glycerol and three fatty acids.
ii	Know the differences between saturated and unsaturated lipids.
iii	Understand how the structure of lipids relates to their role in energy storage, waterproofing and insulation.
iv	Understand how the structure and properties of phospholipids relate to their function in cell membranes.

Students should:	
1.3	**Proteins**
i	Know the structure of an amino acid (structures of specific amino acids are not required).
ii	Understand the formation of polypeptides and proteins (as amino acid monomers linked by peptide bonds in condensation reactions).
iii	Understand the role of ionic, hydrogen and disulfide bonding in the structure of proteins.
iv	Understand the significance of the primary, secondary, tertiary and quaternary structure of a protein in determining the properties of fibrous and globular proteins, including collagen and haemoglobin.
v	Understand how the structure of collagen and haemoglobin are related to their function.
1.4	**DNA and protein synthesis**
i	Know the structure of DNA, including the structure of the nucleotides (purines and pyrimidines), base pairing, the two sugar-phosphate backbones, phosphodiester bonds and hydrogen bonds.
ii	Understand how DNA is replicated semi-conservatively, including the role of DNA helicase, polymerase and ligase.
iii	Know that a gene is a sequence of bases on a DNA molecule coding for a sequence of amino acids in a polypeptide chain.
iv	Know the structure of mRNA including nucleotides, the sugar phosphate backbone and the role of hydrogen bonds.
v	Know the structure of tRNA, including nucleotides, the role of hydrogen bonds and the anticodon.
vi	Understand the processes of transcription in the nucleus and translation at the ribosome, including the role of sense and anti-sense DNA, mRNA, tRNA and the ribosomes.
vii	Understand the nature of the genetic code, including triplets coding for amino acids, start and stop codons, degenerate and non-overlapping nature, and that not all the genome codes for proteins.
viii	Understand the term gene mutation as illustrated by base deletions, insertions and substitutions.
ix	Understand the effect of point mutations on amino acid sequences, as illustrated by sickle cell anaemia in humans.

Students should:	
1.5	**Enzymes**
i	Know the structure of enzymes as globular proteins.
ii	Understand the concepts of specificity and the induced fit hypothesis.
iii	Understand that enzymes are catalysts that reduce activation energy.
iv	Understand how temperature, pH, substrate and enzyme concentration affect the rate of enzyme activity.
CORE PRACTICAL 1: Investigate a factor affecting the initial rate of an enzyme–controlled reaction.	
v	Understand how the initial rate of enzyme activity can be measured and why this is important.
vi	Understand how enzymes can be affected by competitive, non-competitive and end-product inhibition.
vii	Know that enzymes catalyse a wide range of intracellular reactions as well as extracellular ones.
1.6	**Inorganic ions**
i	Understand the role in plants of: • nitrate ions – to make DNA and amino acids • calcium ions – to form calcium pectate for the middle lamellae • magnesium ions – to produce chlorophyll • phosphate ions – to make ADP and ATP.
1.7	**Water**
i	Understand the importance of the dipole nature of water leading to hydrogen bonding and the significance of the following to organisms: • high specific heat capacity • polar solvent • surface tension • incompressibility • maximum density at 4 °C.

Topic 2: Cells, Viruses and Reproduction of Living Things

This topic considers the ultrastructure of prokaryotes, eukaryotes and viruses. Details of the types of nuclear division are included and how these are involved in animal and plant reproduction. Microscopy and observational skills are developed through the preparation of stained plant tissue.

Opportunities for developing mathematical skills within this topic include: recognising and using expressions in decimal and standard form; making order of magnitude calculations; changing the subject of an equation; plotting two variables from experimental or other data. (Please see *Appendix 6: Mathematical skills and exemplifications* for further information.)

Students should:	
2.1	**Eukaryotic and prokaryotic cell structure and function**
i	Understand that cell theory is a unifying concept that states that cells are a fundamental unit of structure, function and organisation in all living organisms.
ii	Understand that in complex organisms, cells are organised into tissues, organs, and organ systems.
iii	Know the ultrastructure of prokaryotic cells and the structure of organelles, including: nucleoid, plasmids, 70S ribosomes and cell wall.
iv	Be able to distinguish between Gram positive and Gram negative bacterial cell walls and understand why each type reacts differently to some antibiotics.
v	Know the ultrastructure of eukaryotic cells and the functions of organelles, including: nucleus, nucleolus, 80S ribosomes, rough and smooth endoplasmic reticulum, mitochondria, centrioles, lysosomes, Golgi apparatus, cell wall, chloroplasts, vacuole and tonoplast.
vi	Know how magnification and resolution can be achieved using light and electron microscopy.
vii	Understand the importance of staining specimens in microscopy.
CORE PRACTICAL 2: Use of the light microscope, including simple stage and eyepiece micrometers and drawing small numbers of cells from a specialised tissue.	

Students should:	
2.2	**Viruses**
i	Understand that the classification of viruses is based on structure and nucleic acid types as illustrated by λ (lambda) phage (DNA), tobacco mosaic virus and Ebola (RNA) and human immunodeficiency virus (RNA retrovirus).
ii	Know the lytic cycle of a virus and latency.
iii	Know that viruses are not living cells and so antivirals must work by inhibiting virus replication.
iv	Know that as viruses can be difficult to treat once infection has occurred, the focus of disease control should be on preventing the spread, as exemplified by the 2014 Ebola outbreak in West Africa.
v	Be able to evaluate the ethical implications of using untested drugs during epidemics.
2.3	**Eukaryotic cell cycle and division**
i	Know that the cell cycle is a regulated process in which cells divide into two identical daughter cells, and that this process consists of three main stages: interphase, mitosis and cytokinesis.
ii	Understand what happens to genetic material during the cell cycle, including the stages of mitosis.
iii	Understand how mitosis contributes to growth, repair and asexual reproduction.
CORE PRACTICAL 3: Make a temporary squash preparation of a root tip to show stages of mitosis in the meristem under the light microscope.	
iv	Understand how meiosis results in haploid gametes, including the stages of meiosis.
v	Understand that meiosis results in genetic variation through recombination of alleles, including independent assortment and crossing over.
vi	Understand what chromosome mutations are, as illustrated by translocations.
vii	Understand how non-disjunction can lead to polysomy, including Down's syndrome, and monosomy, including Turner's syndrome.
2.4	**Sexual reproduction in mammals**
i	Understand the processes of oogenesis and spermatogenesis.
ii	Understand the events of fertilisation from the first contact between the gametes to the fusion of nuclei.
iii	Understand the early development of the embryo to blastocyst stage.

Students should:
2.5 Sexual reproduction in plants
i Understand how a pollen grain forms in the anther and the embryo sac forms in the ovule.
ii Understand how the male nuclei formed by division of the generative nucleus in the pollen grain reach the embryo sac, including the roles of the tube nucleus, pollen tube and enzymes.
CORE PRACTICAL 4: Investigate the effect of sucrose concentrations on pollen tube growth or germination.
iii Understand the process of double fertilisation inside the embryo sac to form a triploid endosperm and a zygote.

Topic 3: Classification and Biodiversity

This topic considers the evidence used in the development of models for the classification of organisms. It also considers the limitations of these models. The topic includes the principles underlying natural selection and how this can lead to speciation.

Opportunities for developing mathematical skills within this topic include the principles of sampling as applied to scientific data, and assessment of species diversity using a formula to calculate an index of diversity. (Please see *Appendix 6: Mathematical skills and exemplifications* for further information.)

Students should:	
3.1	**Classification**
i	Know that the classification system consists of a hierarchy of domain, kingdom, phylum, class, order, family, genus and species.
ii	Understand the limitations of the definition of a species as a group of organisms with similar characteristics that interbreed to produce fertile offspring.
iii	Understand why it is often difficult to assign organisms to any one species or to identify new species.
iv	Understand how gel electrophoresis can be used to distinguish between species and determine evolutionary relationships.
v	Know that DNA sequencing and bioinformatics can be used to distinguish between species and determine evolutionary relationships.
vi	Understand the role of scientific journals, the peer review process and scientific conferences in validating new evidence supporting the accepted scientific theory of evolution.
vii	Understand the evidence for the three-domain model of classification as an alternative to the five-kingdom model and the role of the scientific community in validating this evidence.
3.2	**Natural selection**
i	Understand how evolution can come about through natural selection acting on variation bringing about adaptations.
ii	Understand how organisms occupy niches according to physiological, behavioural and anatomical adaptations.
iii	Understand how reproductive isolation can lead to allopatric and sympatric speciation.
iv	Understand that there is an evolutionary race between pathogens and the development of medicines to treat the diseases they cause.

Students should:

3.3 Biodiversity

i Know that biodiversity can be assessed at different scales:

- within a habitat at the species level using a formula to calculate an index of diversity:

$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

- within a species at the genetic level by looking at the variety of alleles in the gene pool of a population.

ii Understand the ethical and economic reasons (ecosystem services) for the maintenance of biodiversity.

iii Understand the principles of ex-situ (zoos and seed banks) and in-situ conservation (protected habitats), and the issues surrounding each method.

Topic 4: Exchange and Transport

This topic considers the requirements for transport mechanisms in cells and mass flow systems in organisms. The roles of the components of the mammalian circulatory system and the vascular system in plants are studied. Practical skills are developed through the investigation of factors that affect membrane permeability and water potential of plant tissues.

Opportunities for developing mathematical skills within this topic include: recognising and making use of appropriate units in calculations; recognising and using expressions in decimal and standard form; using ratios, fractions and percentages; finding arithmetic means; solving algebraic equations; translating information between graphical, numerical and algebraic forms; plotting variables from experimental data; understanding that y = mx + c represents a linear relationship; determining the intercept of a graph; calculating rate of change from a graph showing a linear relationship; calculating the circumferences, surface areas and volumes of regular shapes. (Please see *Appendix 6: Mathematical skills and exemplifications* for further information.)

Students should:

4.1 Surface area to volume ratio

i Understand how surface area to volume ratio affects transport of molecules in living organisms.

ii Understand why organisms need a mass transport system and specialised gas exchange surfaces as they increase in size.

4.2 Cell transport mechanisms

i Know the structure of the cell surface membrane with reference to the fluid mosaic model.

ii Understand how passive transport is brought about by:

- diffusion
- facilitated diffusion (through carrier proteins and protein channels)
- osmosis.

iii Understand how the properties of molecules affects how they are transported, including solubility, size and charge.

iv Know that large molecules can be transported into and out of cells through the formation of vesicles, in the processes of endocytosis and exocytosis.

CORE PRACTICAL 5: Investigate the effect of temperature on beetroot membrane permeability.

CORE PRACTICAL 6: Determine the water potential of plant cells.

Water potential = turgor pressure + osmotic potential

$$\psi = P + \pi$$

Students should:
4.2 Cell transport mechanisms (*continued*)
v Understand the process of active transport, including the role of ATP.
vi Know that phosphorylation of ADP requires energy and that hydrolysis of ATP provides an accessible supply of energy for biological processes.
4.3 Gas exchange
i Understand how insects, fish and mammals are adapted for gas exchange.
CORE PRACTICAL 7: Dissect an insect to show the structure of the gas exchange system, taking into account the safe and ethical use of organisms.
ii Understand gas exchange in flowering plants, including the role of stomata, gas exchange surfaces in the leaf and lenticels.
4.4 Circulation
i Know the structure of the heart, arteries, veins and capillaries.
ii Understand the advantages of a double circulatory system in mammals over the single circulatory systems in bony fish, including the facility for blood to be pumped to the body at higher pressure and the splitting of oxygenated and deoxygenated blood.
iii Know the sequence of events of the cardiac cycle.
iv Understand myogenic stimulation of the heart, including the roles of the sinoatrial node (SAN), atrioventricular node (AVN) and bundle of His.
v Be able to interpret data showing ECG traces and pressure changes during the cardiac cycle.
vi Know the structure of blood as plasma and blood cells, to include erythrocytes and leucocytes (neutrophils, eosinophils, monocytes and lymphocytes).
vii Know the function of blood as transport, defence, and formation of lymph and tissue fluid.
viii Understand the role of platelets and plasma proteins in the sequence of events leading to blood clotting, including: • platelets form a plug and release clotting factors, including thromboplastin • prothrombin changes to its active form, thrombin • soluble fibrinogen forms insoluble fibrin to cover the wound.
ix Understand the stages that lead to atherosclerosis, its effect on health and the factors that increase the risk of its development.

Students should:	
4.5	**Transport of gases in the blood**
i	Understand the structure of haemoglobin in relation to its role in the transport of respiratory gases, including the Bohr effect.
ii	Understand the oxygen dissociation curve of haemoglobin.
iii	Understand the similarities and differences between the structures and functions of haemoglobin and myoglobin.
iv	Understand the significance of the oxygen affinity of fetal haemoglobin as compared to adult haemoglobin.
4.6	**Transfer of materials between the circulatory system and cells**
i	Understand how the interchange of substances occurs through the formation and reabsorption of tissue fluid, including the effects of hydrostatic pressure and oncotic pressure.
ii	Know that tissue fluid that is not reabsorbed is returned to the blood via the lymph system.
4.7	**Transport in plants**
i	Understand the structure of xylem and phloem tissues in relation to their role in transport.
ii	Understand how water can be moved through plant cells by the apoplastic and symplastic pathways.
iii	Understand how the cohesion-tension model explains the transport of water from plant roots to shoots.
iv	Understand how temperature, light, humidity and movement of air affect the rate of transpiration.
v	Understand the strengths and weaknesses of the mass-flow hypothesis in explaining the movement of sugars through phloem tissue.
CORE PRACTIAL 8: Investigate factors affecting water uptake by plant shoots using a potometer.	

Topic 5: Energy for Biological Processes

This topic builds on knowledge of carbohydrates and enzymes. It considers the sources of energy in living organisms and how energy transfers take place. Details of the stages in respiration and photosynthesis, the roles of co-enzymes and electrons along with the uses of intermediates are included. Practical skills are developed in the investigations of photosynthetic pigments and the factors that affect rates of respiration and photosynthesis.

Opportunities for developing mathematical skills within this topic include: translating information between graphical, numerical and algebraic forms; plotting variables from experimental data; understanding that y = mx + c represents a linear relationship; determining the intercept of a graph; calculating rate of change from a graph showing a linear relationship; determining the intercept of a graph; drawing and using the slope of a tangent to a curve as a measure of rate of change. (Please see *Appendix 6: Mathematical skills and exemplifications* for further information.)

Students should:	
5.1	**Aerobic respiration**
i	Know that cellular respiration yields ATP which is used as a source of energy for metabolic reactions, and the process also generates heat.
ii	Know the different stages in aerobic respiration, including: • glycolysis in the cytoplasm • link reaction • Krebs cycle • oxidative phosphorylation in mitochondria.
5.2	**Glycolysis**
i	Understand the conversion of monosaccharides to pyruvate during glycolysis in the cytoplasm, including: • the phosphorylation of hexose molecules by ATP • breakdown to glycerate 3-phosphate (GP) • production of reduced coenzyme (NADH) and ATP (details of intermediate compounds and other reactions are not required).
5.3	**Link reaction and Krebs cycle**
i	Know that the link reaction and Krebs cycle take place in the mitochondrial matrix.
ii	Understand that during the complete oxidation of pyruvate the events of the link reaction and the Krebs cycle result in the removal of carbon atoms to produce: • carbon dioxide • reduced coenzyme (NADH) • ATP (detailed knowledge of the intermediate compounds in the Krebs cycle is not required).

Students should:
5.4 Oxidative phosphorylation
i Know that the electron transport chain takes place in the inner mitochondrial membrane.
ii Understand the role of the electron transport chain in generating ATP (oxidative phosphorylation).
iii Understand the role of oxygen as a terminal electron acceptor forming water.
iv Understand how ATP is synthesised by chemiosmosis.
v Understand the importance of mitochondrial membranes in this process.
5.5 Anaerobic respiration
i Know that anaerobic respiration is the partial breakdown of hexoses to produce a limited yield of ATP in the absence of oxygen.
ii Understand the difference in ATP yields from one molecule of hexose sugar in aerobic conditions compared with anaerobic conditions.
iii Understand how lactate as a by-product of anaerobic respiration affects mammalian muscle contraction.
iv Understand how anaerobic respiration in plants results in ethanol formation.
CORE PRACTICAL 9: Investigate factors affecting the rate of aerobic or anaerobic respiration using a respirometer, taking into account the safe and ethical use of organisms.
5.6 Photosynthetic pigments
i Understand what is meant by absorption and action spectra.
CORE PRACTICAL 10: Investigate the effects of different wavelengths of light on the rate of photosynthesis.
ii Understand why many plants have a variety of different photosynthetic pigments.
CORE PRACTICAL 11: Investigate the presence of different chloroplast pigments using chromatography.

Students should:

5.7 Photosynthesis

i Know the structure of chloroplasts, including: envelope, stroma, grana and lamellar structure.

Light-dependent stage:

ii Understand the role of the thylakoid membranes in the light-dependent stage of photosynthesis.

iii Understand that the processes of cyclic and non-cyclic photophosphorylation result in the production of reduced NADP, ATP and oxygen.

Light-independent stage:

iv Understand the role of the stroma in the light-independent stage of photosynthesis.

v Understand how carbon dioxide is fixed by combination with 5C ribulose bisphosphate (RuBP) to form glycerate 3-phosphate (GP) using the enzyme ribulose bisphosphate carboxylase (RUBISCO).

vi Understand how reduced NADP and ATP from the light-dependent stage are used:

- to synthesise glyceraldehyde phosphate (GALP) from GP
- to regenerate 5C ribulose bisphosphate in the Calvin cycle (details of intermediate compounds are not required).

vii Understand how GALP is used as a raw material in the production of monosaccharides, amino acids and other molecules.

viii Understand the factors that limit photosynthesis including carbon dioxide, light intensity and temperature.

Topic 6: Microbiology and Pathogens

This topic builds on knowledge of prokaryotes, eukaryotes, viruses and transport systems. It considers how some microorganisms act as pathogens. Details of how the human body responds to infection are included. The social, economic and ethical implications of the methods of treatment and control of the spread of infection are discussed. Microbial techniques are used in the isolation of bacteria and the investigation of the factors that affect their rate of growth.

Opportunities for developing mathematical skills within this topic include: recognising and making use of appropriate units in calculations, recognising and using expressions in decimal and standard form; using ratios, fractions and percentages; estimating results; finding and using power, exponential and logarithmic functions; using an appropriate number of significant figures; finding arithmetic means; using logarithms in relation to quantities that range over several orders of magnitude; translating information between graphical, numerical and algebraic forms; plotting two variables from experimental data; determining the intercept of a graph; drawing and using the slope of a tangent to a curve as a measure of rate of change. (Please see *Appendix 6: Mathematical skills and exemplifications* for further information.)

Students should:	
6.1	**Microbial techniques**
i	Understand the basic aseptic techniques used in culturing organisms.
ii	Understand the principles and techniques involved in culturing microorganisms.
iii	Understand the use of different media (broth cultures, agar and selective media).
iv	Understand the different methods of measuring the growth of a bacterial culture as illustrated by cell counts, dilution plating, mass and optical methods (turbidity).
v	Understand the different phases of a bacterial growth curve (lag phase, log phase, stationary phase and death phase) and calculate exponential growth rate constants.
CORE PRACTICAL 12: Investigate the rate of growth of bacteria in liquid culture taking into account the safe and ethical use of organisms.	
CORE PRACTICAL 13: Isolate individual species from a mixed culture of bacteria using streak plating taking into account the safe and ethical use of organisms.	
6.2	**Bacteria as pathogens**
i	Understand that bacteria can be agents of infection, invading and destroying host tissues and producing toxins.
ii	Understand that pathogenic effects can be produced by exotoxins (*Staphylococcus* spp.), endotoxins (*Salmonella* spp.) and invasion of host tissue (*Mycobacterium tuberculosis*).

Students should:	
6.3	**Action of antibiotics**
i	Understand the action of bactericidal and bacteriostatic antibiotics, as illustrated by penicillin and tetracycline.
6.4	**Antibiotic resistance**
i	Understand the development and spread of antibiotic resistance in bacteria.
ii	Understand the methods and difficulties of controlling the spread of antibiotic resistance in bacteria.
6.5	**Other pathogenic agents**
i	Understand the transmission, mode of infection and pathogenic effect of the following: • stem rust fungus on cereal crops (*Puccinia graminis* on wheat) • influenza virus • the malarial parasite (*Plasmodium spp*). (Detailed life cycles are not required.)
6.6	**Problems of controlling endemic diseases**
i	Understand the social and economic and ethical implications of different control methods for endemic malaria and the role of the scientific community in validating these methods.
6.7	**Response to infection**
i	Know the mode of action of macrophages, neutrophils and lymphocytes.
ii	Understand the development of the humoral immune response, including the role of: • antigen presenting T cells • T helper cells and cytokines • B cells • clonal selection • plasma cells • antibodies.
iii	Understand the development of the cell-mediated immune response including the role of: • antigen presenting cells • T helper cells and cytokines • T killer cells.

Students should:	
6.7	**Response to infection *continued***
iv	Understand the role of T and B memory cells in the secondary immune response.
v	Understand how immunity can be natural or artificial, and active or passive.
vi	Understand how vaccination can be used in the control of disease and the development of herd immunity.
vii	Understand the potential issues in populations where a proportion choose not to vaccinate.

Topic 7: Modern Genetics

This topic builds on the knowledge of nucleic acids and proteins and how they are involved in gene expression. Knowledge of epigenetics, the use of stem cells and how these are contributing to medical advances are considered. The ethical implications of the use of gene technology in scientific developments are discussed.

Opportunities for developing mathematical skills within this topic include: recognising and using expressions in decimal and standard form; using an appropriate number of significant figures. (Please see *Appendix 6: Mathematical skills and exemplifications* for further information.)

Students should:	
7.1	**Using gene sequencing**
i	Understand what is meant by the term genome.
ii	Understand how PCR can be used to amplify DNA samples, and how these samples can be used: • to predict the amino acid sequence of proteins and possible links to genetically determined conditions, using gene sequencing. • in forensic science, to identify criminals and to test paternity, using DNA profiling.
7.2	**Factors affecting gene expression**
i	Know that transcription factors are proteins that bind to DNA.
ii	Understand the role of transcription factors in regulating gene expression.
iii	Understand how post–transcription modification of mRNA in eukaryotic cells (RNA splicing) can result in different products from a single gene.
iv	Understand that gene expression can be changed by epigenetic modification, including non-coding RNA, histone modification and DNA methylation.
v	Know that epigenetic modification is important in ensuring cell differentiation.
7.3	**Stem cells**
i	Understand what is meant by a stem cell, including the differences between totipotent, pluripotent and multipotent stem cells.
ii	Understand that pluripotent stem cells from embryos provide opportunities to develop new medical advances although there are ethical considerations.
iii	Understand how epigenetic modifications can result in totipotent stem cells in the embryo developing into pluripotent cells in the blastocyst and finally into fully differentiated somatic cells.

Students should:	
7.3	**Stem cells *continued***
iv	Understand how differentiated fibroblasts can be reprogrammed to form induced pluripotent stem cells (iPS cells) by the artificial introduction of named genes.
v	Understand why the use of iPS stem cells may be less problematic than the use of embryonic stem cells.
7.4	**Gene technology**
i	Understand how recombinant DNA can be produced, including the role of restriction endonucleases and DNA ligase.
ii	Understand how recombinant DNA can be inserted into other cells, and the use of various vectors such as viruses and gene guns.
iii	Understand how antibiotic resistance marker genes and replica plating are used to identify recombinant cells.
iv	Understand how 'knockout' mice can be used as a valuable animal model to investigate gene function.
v	Understand the process of genetic modification of soya beans and how it has been used to improve production, including altering the balance of fatty acids to prevent oxidation of soya products.
vi	Understand why the widespread use of genetic modification of major commercial crops and other transgenic processes have caused public debate of their advantages and disadvantages.

Topic 8: Origins of Genetic Variation

This topic builds on the knowledge of meiosis and natural selection. It considers the dihybrid inheritance of alleles and genes. The inheritance of unlinked and linked genes is studied. The effect of selection pressures on the allele frequencies in gene pools and their impact on speciation are discussed.

Opportunities for developing mathematical skills within this topic include: using ratios, fractions and percentages; understanding simple probability; using Chi squared tests; understanding measures of dispersion, including standard deviation and range; solving algebraic equations; the analysis of allele frequencies using the Hardy-Weinberg equation. (Please see *Appendix 6: Mathematical skills and exemplifications* for further information.)

Students should:	
8.1	**Origins of genetic variation**
i	Understand that mutations are the source of new variations and that the processes of random assortment and crossing over during meiosis give rise to new combinations of alleles in gametes.
ii	Understand how random fertilisation during sexual reproduction brings about genetic variation.
8.2	**Transfer of genetic information**
i	Understand the terms 'genotype and phenotype',' homozygote and heterozygote', 'dominance', 'recessive', 'codominance' and 'multiple alleles'.
ii	Be able to construct genetic crosses and pedigree diagrams.
iii	Understand the inheritance of two non-interacting unlinked genes.
iv	Understand that autosomal linkage results from the presence of alleles on the same chromosome and that the results of crosses can be explained by the events of meiosis, including black/grey body and long/vestigial wing in Drosophila.
v	Understand sex linkage on the X chromosome, including haemophilia in humans.
vi	Be able to use chi squared tests to test the significance of the difference between observed and expected results.
8.3	**Gene pools**
i	Understand that selection pressures acting on the gene pool change allele frequencies in the population, including: • stabilising selection maintaining continuity in a population • disruptive selection leading to changes or speciation.
ii	Understand that sometimes changes in allele frequencies can be the result of chance and not selection, including genetic drift.

Students should:	
8.3	**Gene pools *continued***
iii	Understand that allele frequencies can be influenced by: • population bottlenecks • founder effect.
iv	Understand how the Hardy-Weinberg equation can be used to monitor changes in the allele frequencies in a population.

Topic 9: Control Systems

This topic builds on knowledge of transport mechanisms and considers the processes of chemical and nervous coordination. Details of the role of plant growth substances and hormonal control in mammals are included. Osmoregulation in mammals adapted to dry environments is considered. Details of the effect of drugs on the transmission of nerve impulses are studied. Practical skills are developed in the investigation of the effect of gibberellin on germination.

Opportunities for developing mathematical skills within this topic include: making use of appropriate units in calculations; using expressions in decimal and standard form; using ratios, fractions and percentages; interpreting frequency tables and diagrams, bar charts and histograms; understanding simple probability; translating information between graphical, numerical and algebraic forms; plotting variables from experimental data; understanding that y = mx + c represents a linear relationship; determining the intercept of a graph; calculating rate of change from a graph; using the slope of a tangent to a curve as a measure of rate of change. (Please see *Appendix 6: Mathematical skills and exemplifications* for further information.)

Students should:	
9.1	**Homeostasis**
i	Know that homeostasis is the maintenance of a state of dynamic equilibrium.
ii	Understand the importance of maintaining pH, temperature and water potential in the body.
iii	Understand what is meant by negative feedback and positive feedback control.
9.2	**Chemical control in mammals**
i	Understand the principles of mammalian hormone production by endocrine glands and their mode of action involving receptors on target cells.
ii	Know that there are two main modes of action in hormones: • hormones attach to receptor sites and trigger the release of a second messenger that activates specific enzymes in the cell, including adrenaline • hormones enter cells and bind directly to transcription factors, including oestrogen.

Students should:
9.3 Chemical control in plants
i Understand that chemical control in plants is brought about by plant growth substances such as auxins, cytokinins and gibberellins.
CORE PRACTICAL 14: Investigate the effect of gibberellin on the production of amylase in germinating cereals using a starch agar assay.
ii Know that auxin has several effects, including cell elongation, suppression of lateral buds (apical dominance) and promoting root growth.
iii Understand that plant growth substances often interact with each other as shown by the antagonistic actions of cytokinin and auxin on apical dominance.
iv Understand how phytochrome controls flowering and photomorphogenesis.
9.4 Structure and function of the mammalian nervous system
i Know that the mammalian nervous system is composed of the central and peripheral nervous systems.
ii Know the structure of the spinal cord.
iii Know the location and main functions of: • the medulla oblongata – controls breathing and heart rate • cerebellum – controls balance and coordination of movement • cerebrum – initiates movement • hypothalamus – temperature regulation and osmoregulation.
iv Know that the peripheral nervous system is divided into autonomic and voluntary systems.
v Understand why the autonomic nervous system is divided into sympathetic and parasympathetic systems, which act antagonistically.

Students should:	
9.5	**Nervous transmission**
i	Understand how the properties of the axon membrane and the transport of Na^+ ions and K^+ ions result in a resting potential.
ii	Understand how an action potential is formed and how it is propagated along an axon.
iii	Understand why the speed of transmission along myelinated axons is greater than along non-myelinated axons, including the role of saltatory conduction.
iv	Understand the structure and function of a synapse, including the role of transmitter substances limited to acetylcholine and noradrenaline.
v	Understand the formation and effects of excitatory and inhibitory postsynaptic potentials.
9.6	**Effects of drugs on the nervous system**
i	Understand how the effects of drugs can be caused by their influence on synaptic transmission, including: • nicotine (mimicking effects of acetylcholine) • lidocaine (blocking voltage gated Na^+ ion channels) • cobra venom (blocking acetylcholine receptors).
9.7	**Detection of light by mammals**
i	Know the structure of the human retina.
ii	Understand the role of the rhodopsin in initiating action potentials.
iii	Understand how the distribution of human rod and cone cells maintain vision in different light intensities.
9.8	**Control of heart rate in mammals**
i	Understand how the autonomic nervous system controls heart rate including: • aortic and carotid baroreceptors and chemoreceptors • cardiac centre in the medulla oblongata • sympathetic nerve stimulated to release noradrenaline at the SAN • parasympathetic nerve stimulated to release acetylcholine at the SAN.
ii	Understand the role of the autonomic nervous system in causing the release of adrenaline to increase heart rate.

Students should:	
9.9	**Osmoregulation and temperature regulation**
i	Know the gross and microscopic structure of the mammalian kidney.
ii	Understand how urea is produced in the liver from excess amino acids (details of the ornithine cycle are not required) and how it is removed from the bloodstream by ultrafiltration.
iii	Understand how solutes are selectively reabsorbed in the proximal tubule and how the Loop of Henle acts as a counter-current multiplier to increase the reabsorption of water.
iv	Understand how the pituitary gland and osmoreceptors in the hypothalamus, combined with the action of antidiuretic hormone (ADH) bring about negative feedback control of mammalian plasma concentration.
v	Understand how the kidney of a kangaroo rat (*Dipodomys sp*.) is adapted for life in a dry environment.
vi	Understand that an endotherm is able to produce heat through metabolic processes but an ectotherm must rely on the external environment.
vii	Understand how an endotherm is able to regulate its temperature through behaviour, and also physiologically through the autonomic nervous system, including the role of thermoreceptors, hypothalamus and the skin.

Topic 10: Ecosystems

This topic considers the interactions between the organisms and the environment within an ecosystem. It includes details of how biotic and abiotic factors are involved in the development of ecosystems over time. Human influences on ecosystems are also discussed along with the need for conservation.

Opportunities for developing mathematical skills within this topic include: estimating results; constructing and interpresting frequency tables and diagrams, bar charts and histograms; understanding principles of sampling, including use of a formula to calculate an index of diversity; understanding the terms mean, median and mode; selecting and using statistical tests, including the Chi squared test, Student's t-test of difference, Spearman's rank, correlation coefficient; standard deviation and range. (Please see *Appendix 6: Mathematical skills and exemplifications* for further information.)

Students should:

10.1 The nature of ecosystems

i Understand what is meant by the term ecosystem and that they range in size.

ii Understand what is meant by trophic levels.

iii Understand the advantages and disadvantages of pyramids of numbers, biomass (dry) and energy as useful representations of ecosystem structure and how biomass and energy are transferred within them.

iv Know the ecological techniques used to assess abundance and distribution of organisms in a natural habitat, including types of quadrat, transects, ACFOR scales, percentage cover and individual counts.

v Be able to select appropriate ecological techniques according to the ecosystem and organisms to be studied.

CORE PRACTICAL 15: Investigate the effect of different sampling methods on estimates of the size of a population taking into account the safe and ethical use of organisms.

vi Be able to use statistical tests to analyse data, including t-test and Spearman rank correlation coefficient.

10.2 Energy transfer through ecosystems

i Understand how energy is transferred between trophic levels using the terms 'net primary productivity' and 'gross primary productivity'.

ii Be able to calculate the efficiency of energy transfer between different trophic levels and account for the loss of energy at each level.

iii Understand the significance of microorganisms in the recycling of nutrients within an ecosystem.

Students should:
10.3 Changes in ecosystems i Understand how ecosystems can develop over time, including use of the terms colonisation and succession and types of climax communities. ii Understand the effects of biotic and abiotic factors on population size. CORE PRACTICAL 16: Investigate the effect of one abiotic factor on the distribution or morphology of one species taking into account the safe and ethical use of organisms.
10.4 Human effects on ecosystems i Understand data relating to human influences on ecosystems, including climate change and depletion of biological resources, including overfishing. ii Understand the effect that treaties such as CITES have had on global biodiversity. iii Understand the idea that sustainability of resources depends on effective management of the conflict between human needs and conservation, as illustrated by attempts to conserve fish stocks and reduce possible causes of climate change. iv Understand the role of the scientific journals, the peer review process and scientific conferences in validating evidence related to the debate about climate change.

Science Practical Endorsement

Overview

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 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 CPAC 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.
- Each student will keep an appropriate record of their practical work, including 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. These questions may draw on, or range beyond, the practical activities included in the specification.

Setting practical work

Teaching and learning

Teachers should ensure that the core practicals listed in the subject content are incorporated into teaching and learning and that students carry them out. This is to support development of competency for the practical endorsement but also because students will be indirectly assessed on their practical skills in the examinations. Teachers should consider setting additional practical work to support teaching and learning.

Teachers must devise and retain a teaching plan that shows when practicals will be covered in teaching and learning.

Students should attempt all 16 practicals given in the qualification content.

Conditions for assessing practical work

Authenticity

Students and teachers must sign the Practical competency authentication sheet (see *Appendix 4).*

Collaboration

Students may work in pairs on some practicals, where this is appropriate, provided they are able to produce individual evidence to meet the competency statements.

Feedback

Teachers may help students to understand instructions and may provide feedback to support development of the competencies. Teachers should be confident that students have developed their skills and thus students should be able to demonstrate the competencies independently by the end of the course.

Resources

Students must have access to the equipment needed to carry out the core practicals. Students must also have access to IT and internet facilities.

Supervision

Teachers must ensure that students are supervised appropriately.

Evidence of practical work

Evidence should be collected of practical work that is sufficient to show that the competencies have been achieved. Evidence may take a variety of forms.

The practical activities prescribed in the specification provide opportunities for demonstrating competence in all the skills identified, together with the use of apparatus and techniques for each subject. However, students can also demonstrate these competencies in any additional practical activity undertaken throughout the course of study which covers the requirements of *Appendix 5c*.

Observations and notes by teachers

Teachers should observe sufficient student practicals to ensure that competencies have been achieved.

Student records

Students should keep notes of their practical work sufficient to show evidence of the practical competencies on making and recording observations and researching, referencing and reporting.

Assessing practical work

Teachers should make a judgement of student practical competence using the Common Practical Assessment Criteria on the following pages. Teachers should include any comments on the Practical competency authentication sheet (see *Appendix 4*) to justify the decision made.

In order to achieve a pass, students will need to:

- develop these competencies by carrying out a minimum of 12 practical activities, which allow acquisition of the techniques outlined in the requirements of the specification
- consistently and routinely exhibit the competencies listed in the CPAC before the completion of the A-level course
- keep an appropriate record of their practical work, including their assessed practical activities
- be able to demonstrate and/or record independent evidence of their competency, including evidence of independent application of investigative approaches and methods to practical work.

Common Practical Assessment Criteria (CPAC)

Teachers must assess student practicals against the following competencies.

Criteria for the assessment of GCE Science practical competency for Biology, Chemistry and Physics	
Competency	**The criteria for a pass** In order to be awarded a Pass a learner must, by the end of the practical science assessment, consistently and routinely meet the criteria in respect of each competency listed below. A learner may demonstrate the competencies in any practical activity undertaken as part of that assessment throughout the course of study. Learners may undertake practical activities in groups. However, the evidence generated by each learner must demonstrate that he or she independently meets the criteria outlined below in respect of each competency. Such evidence: (a) will comprise both the learner's performance during each practical activity and his or her contemporaneous record of the work that he or she has undertaken during that activity, and (b) must include evidence of independent application of investigative approaches and methods to practical work.
1. Follows written procedures	a) Correctly follows written instructions to carry out the experimental techniques or procedures.
2. Applies investigative approaches and methods when using instruments and equipment	a) Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting. b) Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments when necessary. c) Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled. d) Selects appropriate equipment and measurement strategies in order to ensure suitably accurate results.

Criteria for the assessment of GCE Science practical competency for Biology, Chemistry and Physics	
3. Safely uses a range of practical equipment and materials	a) Identifies hazards and assesses risks associated with these hazards, making safety adjustments as necessary, when carrying out experimental techniques and procedures in the lab or field. b) Uses appropriate safety equipment and approaches to minimise risks with minimal prompting.
4. Makes and records observations	a) Makes accurate observations relevant to the experimental or investigative procedure. b) 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	a) Uses appropriate software and/or tools to process data, carry out research and report findings. b) Cites sources of information demonstrating that research has taken place, supporting planning and conclusions.

Marking and standardisation

The practical work is assessed by teachers. Pearson Edexcel will support teachers in making judgements against the criteria for assessment.

In coordination with other exam boards, Pearson will monitor how schools provide students with opportunities to develop and demonstrate the required practical skills and how they mark the assessments.

Every school will be monitored at least once in a two-year period in respect of at least one of the A level science subjects. These monitoring visits will be coordinated by JCQ, who will undertake communications with centres to facilitate the allocation of exam board monitoring visits.

In common with other exam boards, Pearson will require centres to provide a statement confirming they have taken reasonable steps to secure that students:

- undertook the minimum number of practical activities, and
- made a contemporaneous record of their work.

If a school fails to provide a statement, or provides a false statement, this will be treated as malpractice and/or maladministration.

Students will only get a certificate for the practical assessment if they achieve at least a grade E in the examined part of the qualification.

Students who do not pass the practical assessment will have a 'Not Classified' outcome included on their certificate unless they were exempt from the assessment because of a disability.

Malpractice

Candidate malpractice

Candidate malpractice refers to any act by a candidate that compromises or seeks to compromise the process of assessment or which undermines the integrity of the qualifications or the validity of results/certificates.

Candidate malpractice in controlled assessments discovered before the candidate has signed the declaration of authentication form does not need to be reported to Pearson.

Candidate malpractice found in controlled assessments after the declaration of authenticity has been signed, and in examinations **must** be reported to Pearson on a *JCQ Form M1* (available at www.jcq.org.uk/exams-office/malpractice). The completed form can be emailed to pqsmalpractice@pearson.com or posted to Investigations Team, Pearson, 190 High Holborn, London, WC1V 7BH. Please provide as much information and supporting documentation as possible. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report candidate malpractice constitutes staff or centre malpractice.

Staff/centre malpractice

Staff and centre malpractice includes both deliberate malpractice and maladministration of our qualifications. As with candidate malpractice, staff and centre malpractice is any act that compromises or seeks to compromise the process of assessment or undermines the integrity of the qualifications or the validity of results/certificates.

All cases of suspected staff malpractice and maladministration **must** be reported immediately, before any investigation is undertaken by the centre, to Pearson on a *JCQ Form M2(a)* (available at www.jcq.org.uk/exams-office/malpractice). The form, supporting documentation and as much information as possible can be emailed to pqsmalpractice@pearson.com or posted to Investigations Team, Pearson, 190 High Holborn, London, WC1V 7BH. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice itself constitutes malpractice.

More-detailed guidance on malpractice can be found in the latest version of the document *JCQ General and Vocational Qualifications Suspected Malpractice in Examinations and Assessments Policies and Procedures,* available at www.jcq.org.uk/exams-office/malpractice.

Assessment

Assessment summary

Summary of table of assessment

Students must complete all assessment in May/June in any single year.

Paper 1: Advanced Biochemistry, Microbiology and Genetics *Paper code: 9BI0/01	
• Questions draw on content from Topics 1–7. • Questions are broken down into a number of parts. • Availability: May/June • First assessment: 2017 • The assessment is 1 hour 45 minutes. • The assessment consists of 90 marks.	**30% of the total qualification**

Paper 2: Advanced Physiology, Evolution and Ecology *Paper code: 9BI0/02	
• Questions draw on content from Topics 1–4 and Topics 8–10. • Questions are broken down into a number of parts. • Availability: May/June • First assessment: 2017 • The assessment is 1 hour 45 minutes. • The assessment consists of 90 marks.	**30% of the total qualification**

Paper 3: General and Practical Principles in Biology *Paper code: 9BI0/03	
• Questions draw on content from across all topics, Topics 1–10. • Questions are broken down into a number of parts. • The paper will include synoptic questions that may draw on two or more different topics. • Availability: May/June • First assessment: 2017 • The assessment is 2 hours 30 minutes. • The assessment consists of 120 marks.	**40% of the total qualification**

Science Practical Endorsement**	***Paper code: 9BI0/04**

- Internally assessed and externally moderated by Pearson.
- Availability: May/June
- First assessment: 2017
- The practical endorsement is teacher assessed against the Common Practical Assessment criteria (CPAC).

The sample assessment materials can be found in the *Pearson Edexcel Level 3 Advanced GCE in Biology B Sample Assessment Materials* document.

*See *Appendix 3: Codes* for a description of this code and all other codes relevant to this qualification.

** Students will be assessed separately for the Science Practical Endorsement. The Endorsement will not contribute to the overall grade for this qualification, but the result will be recorded on the student's certificate.

Assessment Objectives and weightings

Students must:		% in GCE
AO1	Demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures	31-33
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	41-43
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	25-27
	Total	**100%**

Breakdown of Assessment Objectives

Paper	AO1	AO2	AO3	Total for all Assessment Objectives
Paper 1: Advanced Biochemistry, Microbiology and Genetics	11-13%	12-14%	5-7%	30%
Paper 2: Advanced Physiology, Evolution and Ecology	11-13%	12-14%	5-7%	30%
Paper 3: General and Practical Principles in Biology	8-10%	16-18%	13-15%	40%
Total for this qualification	**31-33%**	**41-43%**	**25-27%**	**100%**

Entry and assessment information

Student entry

Details of how to enter students for the examinations for this qualification can be found in our *UK Information Manual*. A copy is made available to all examinations officers and is available on our website at: www.edexcel.com/iwantto/Pages/uk-information-manual.aspx.

Discount codes and performance tables

Centres should be aware that students who enter for more than one GCE qualification with the same discount code will have only one of the grades they achieve counted for the purpose of the school and college performance tables. This will be the grade for the larger qualification (i.e. the A Level grade rather than the AS grade). If the qualifications are the same size, then the better grade will be counted (please see *Appendix 3: Codes*).

Students should be advised that if they take two GCE qualifications with the same discount code, the colleges, universities and employers to which they wish to progress are likely to take the view that this achievement is equivalent to only one GCE. The same view may be taken if students take two GCE qualifications that have different discount codes but which have significant overlap of content. Before embarking on their programmes, students or their advisers who have any doubts about their subject combinations should check with the institution to which they wish to progress.

Access arrangements, reasonable adjustments and special consideration

Access arrangements

Access arrangements are agreed before an assessment. They allow students with special educational needs, disabilities or temporary injuries to:

- access the assessment
- show what they know and can do without changing the demands of the assessment.

The intention behind an access arrangement is to meet the particular needs of an individual disabled student without affecting the integrity of the assessment. Access arrangements are the principal way in which awarding organisations comply with the duty under the Equality Act 2010 to make 'reasonable adjustments'.

Access arrangements should always be processed at the start of the course. Students will then know what is available and have the access arrangement(s) in place for assessment.

Reasonable adjustments

The Equality Act 2010 requires an awarding organisation to make reasonable adjustments where a person with a disability would be at a substantial disadvantage in undertaking an assessment. The awarding organisation is required to take reasonable steps to overcome that disadvantage.

A reasonable adjustment for a particular person may be unique to that individual and therefore might not be in the list of available access arrangements.

Whether an adjustment will be considered reasonable will depend on a number of factors, which will include:

- the needs of the student with the disability
- the effectiveness of the adjustment
- the cost of the adjustment; and
- the likely impact of the adjustment on the student with the disability and other students.

An adjustment will not be approved if it involves unreasonable costs to the awarding organisation, timeframes or affects the security or integrity of the assessment. This is because the adjustment is not 'reasonable'.

Special consideration

Special consideration is a post-examination adjustment to a student's mark or grade to reflect temporary injury, illness or other indisposition at the time of the examination/ assessment, which has had, or is reasonably likely to have

had, a material effect on a candidate's ability to take an assessment or demonstrate his or her level of attainment in an assessment.

Further information

Please see our website for further information about how to apply for access arrangements and special consideration.

For further information about access arrangements, reasonable adjustments and special consideration, please refer to the JCQ website: www.jcq.org.uk.

Equality Act 2010 and Pearson equality policy

Equality and fairness are central to our work. Our equality policy requires all students to have equal opportunity to access our qualifications and assessments, and our qualifications to be awarded in a way that is fair to every student.

We are committed to making sure that:

- students with a protected characteristic (as defined by the Equality Act 2010) are not, when they are undertaking one of our qualifications, disadvantaged in comparison to students who do not share that characteristic
- all students achieve the recognition they deserve for undertaking a qualification and that this achievement can be compared fairly to the achievement of their peers.

You can find details on how to make adjustments for students with protected characteristics in the policy document *Access Arrangements, Reasonable Adjustments and Special Considerations*, which is on our website, www.edexcel.com/Policies.

Synoptic assessment

Synoptic assessment requires students to work across different parts of a qualification and to show their accumulated knowledge and understanding of a topic or subject area.

Synoptic assessment enables students to show their ability to combine their skills, knowledge and understanding with breadth and depth of the subject.

In this qualification, synoptic assessment can be found in *Paper 3: General and Practical Principles in Biology*.

Awarding and reporting

This qualification will be graded, awarded and certificated to comply with the requirements of the current *Code of Practice* published by the Office of Qualifications and Examinations Regulation (Ofqual).

This qualification will be graded and certificated on a six-grade scale from A* to E using the total subject mark. Individual papers are not graded.

The first certification opportunity for the Pearson Edexcel Level 3 Advanced GCE in Biology B will be 2017.

Students whose level of achievement is below the minimum judged by Pearson to be of sufficient standard to be recorded on a certificate will receive an unclassified U result.

Language of assessment

Assessment of this qualification will be available in English. All student work must be in English.

Other information

Student recruitment

Pearson follows the JCQ policy concerning recruitment to our qualifications in that:

- they must be available to anyone who is capable of reaching the required standard
- they must be free from barriers that restrict access and progression
- equal opportunities exist for all students.

Prior learning and other requirements

There are no prior learning or other requirements for this qualification.

Students who would benefit most from studying this qualification are likely to have a Level 2 qualification such as a GCSE in Additional Science or Biology.

Progression

Students can progress from this qualification to:

- a range of different relevant academic or vocational higher education qualifications
- employment in a relevant sector
- further training.

Relationship between Advanced Subsidiary GCE and Advanced GCE

The content for Advanced GCE in Biology B includes all the content studied at Advanced Subsidiary GCE. The Advanced GCE in Biology B builds on the knowledge, skills, and understanding achieved when studying the Advanced Subsidiary GCE in Biology B.

Progression from Advanced Subsidiary GCE to Advanced GCE

Students who have achieved the Advanced Subsidiary GCE in Biology B can progress to the Advanced GCE in Biology B. They would have covered Topics 1-4 which are common to both qualifications but the additional Topics 5-10 will need to be covered and then all the assessment for the Advanced GCE qualification must be taken at the end of the course.

Relationship between GCSE and Advanced GCE

Students cover Key Stage 4 fundamental core concepts in sciences at GCSE and continue to cover these concepts and additional subject material in the Advanced GCE at Key Stage 5.

Progression from GCSE to Advanced GCE

Students will draw on knowledge and understanding achieved in GCSE Additional Science or GCSE Biology to progress on to an Advanced GCE in Biology B qualification.

Appendices

Appendix 1: Transferable skills

The need for transferable skills

In recent years, higher education institutions and employers have consistently flagged the need for students to develop a range of transferable skills to enable them to respond with confidence to the demands of undergraduate study and the world of work.

The Organisation for Economic Co-operation and Development (OECD) defines skills, or competencies, as 'the bundle of knowledge, attributes and capacities that can be learned and that enable individuals to successfully and consistently perform an activity or task and can be built upon and extended through learning.' [1]

To support the design of our qualifications, the Pearson Research Team selected and evaluated seven global 21st-century skills frameworks. Following on from this process, we identified the National Research Council's (NRC) framework as the most evidence-based and robust skills framework. We adapted the framework slightly to include the Program for International Student Assessment (PISA) ICT Literacy and Collaborative Problem Solving (CPS) Skills.

The adapted National Research Council's framework of skills involves: [2]

Cognitive skills

- **Non-routine problem solving** – expert thinking, metacognition, creativity.
- **Systems thinking** – decision making and reasoning.
- **Critical thinking** – definitions of critical thinking are broad and usually involve general cognitive skills such as analysing, synthesising and reasoning skills.
- **ICT literacy** – access, manage, integrate, evaluate, construct and communicate.[3]

Interpersonal skills

- **Communication** – active listening, oral communication, written communication, assertive communication and non-verbal communication.
- **Relationship-building skills** – teamwork, trust, intercultural sensitivity, service orientation, self-presentation, social influence, conflict resolution and negotiation.
- **Collaborative problem solving** – establishing and maintaining shared understanding, taking appropriate action, establishing and maintaining team organisation.

[1] OECD – *Better Skills, Better Jobs, Better Lives* (OECD Publishing, 2012)

[2] Koenig J A, National Research Council – *Assessing 21st Century Skills: Summary of a Workshop* (National Academies Press, 2011)

[3] PISA – *The PISA Framework for Assessment of ICT Literacy* (2011)

Intrapersonal skills

- **Adaptability** – ability and willingness to cope with the uncertain, handling work stress, adapting to different personalities, communication styles and cultures, and physical adaptability to various indoor and outdoor work environments.
- **Self-management and self-development** – ability to work remotely in virtual teams, work autonomously, be self-motivating and self-monitoring, willing and able to acquire new information and skills related to work.

Transferable skills enable young people to face the demands of further and higher education, as well as the demands of the workplace, and are important in the teaching and learning of this qualification. We will provide teaching and learning materials, developed with stakeholders, to support our qualifications.

Appendix 2: Level 3 Extended Project qualification

What is the Extended Project?

The Extended Project is a standalone qualification that can be taken alongside GCEs. It supports the development of independent learning skills and helps to prepare students for their next step – whether that be higher education or employment. The qualification:

- is recognised by higher education for the skills it develops
- is worth half of an Advanced GCE qualification at grades A*–E
- carries UCAS points for university entry.

The Extended Project encourages students to develop skills in the following areas: research, critical thinking, extended writing and project management. Students identify and agree a topic area of their choice (which may or may not be related to a GCE subject they are already studying), guided by their teacher.

Students can choose from one of four approaches to produce:

- a dissertation (for example an investigation based on predominately secondary research)
- an investigation/field study (for example a practical experiment)
- a performance (for example in music, drama or sport)
- an artefact (for example a creating a sculpture in response to a client brief or solving an engineering problem).

The qualification is coursework based and students are assessed on the skills of managing, planning and evaluating their project. Students will research their topic, develop skills to review and evaluate the information, and then present the final outcome of their project.

Students: what they need to do

The Extended Project qualification requires students to:

- select a topic of interest for an in-depth study and negotiate the scope of the project with their teacher
- identify and draft an objective for their project (for example in the form of a question, hypothesis, challenge, outline of proposed performance, issue to be investigated or commission for a client) and provide a rationale for their choice
- produce a plan for how they will deliver their intended objective
- conduct research as required by the project brief, using appropriate techniques
- carry out the project using tools and techniques safely
- share the outcome of the project using appropriate communication methods, including a presentation.

Teachers: key information

- The Extended Project has 120 guided learning hours (GLH) consisting of:
  - a 40-GLH taught element that includes teaching the technical skills (for example research skills)
  - an 80-GLH guided element that includes mentoring students through the project work.
- Group work is acceptable, however it is important that each student provides evidence of their own contribution and produces their own report.
- 100% externally moderated.
- Four Assessment Objectives: manage, use resources, develop and realise, review.
- Can be run over 1, 1½ or 2 years.
- Can be submitted in January or June.

How to link Extended Project with biology

The Extended Project creates the opportunity to develop transferable skills for progression to higher education and to the workplace through the exploration of either an area of personal interest, or a topic of interest, from within the qualification content.

For example, biology students could choose to carry out an investigation that would enable them to develop their skills in data collection, the development and testing of hypotheses and the application of mathematical models in data analysis.

Skills developed

Through the Extended Project students will develop skills in the following areas:

- independent research, including skills in primary research and the selection of appropriate methods for data collection
- extended reading and academic writing, including reading scientific literature and writing about trends or patterns in data sets
- planning/project management, including the refining of hypotheses to be tested in investigations
- data handling and evaluation, including the comparison of data from primary research with published data and exploration of the significance of results
- evaluation of arguments and processes, including arguments in favour of alternative interpretations of data and evaluation of experimental methodology
- critical thinking.

In the context of the Extended Project, critical thinking refers to the ability to identify and develop arguments for a point of view or hypothesis and to consider and respond to alternative arguments.

Using the Extended Project to support breadth and depth

There is no specified material that students are expected to study and, in the Extended Project, students are assessed on the quality of the work they produce and the skills they develop and demonstrate through completing this work. Students can use the Extended Project to demonstrate *extension* in one or more dimensions:

- ***deepening understanding***: where a student explores a topic in greater depth than in the specification content
- ***broadening skills***: the student learns a new skill. In a biology-based project, this might involve learning to assemble and manipulate an unfamiliar piece of apparatus or learning advanced data-handling techniques
- ***widening perspectives***: the student's project spans different subjects. This might involve discussing historical, philosophical or ethical aspects of a biology-based topic or making links with other subject areas such as chemistry or geography.

Choosing topics and narrowing down to a question

A dissertation, typically around 6000 words in length, involves addressing a research question through a literature review and argumentative discussion while an investigation/field study involves data collection and analysis, leading to a written report of around 5000 words.

For example, consider a student with an interest in genetic testing. After some initial research, the student decided to explore the risks and benefits associated with direct to consumer genetic testing. In the literature review of the project, the student researched the background to genetic testing and looked at the work of some of the companies which offer to do tests. The student created a questionnaire survey to elicit information about people's attitudes towards testing and their knowledge of the potential risks and benefits. The survey was piloted then repeated with a sample of 50 people. The student's data from this survey were compared with published data, and the trends and patterns in data analysed, with consideration of the significance of the results obtained. Finally, the student's project ended with a review of the effectiveness of the investigation and an oral presentation of the main findings and arguments considered.

Biology-based dissertation projects can cover a wide variety of topics, as these examples illustrate:

- Is it ethical to use stem cells for medical purposes?
- Should restrictions be placed on research into genetic enhancement?
- Is the use of animal experimentation justifiable?
- Is autism genetic?

Examples of biology-based investigations include:

- Can changing owl behaviour be monitored through pellet studies?
- How has marina development affected local marshland biodiversity?
- Can pollution be effectively monitored by water quality in a local stream?
- Can monitoring a fitness programme help improve hurdling performance?

There is also scope for biology-based artefact Extended Projects. For example, a student might set out to design, make and test an item of apparatus. Extended Projects involving a performance can also be biology based, for example, a social issue relating to biology could be explored through drama.

Appendix 3: Codes

Type of code	Use of code	Code number
Discount codes	Every qualification eligible for performance tables is assigned a discount code indicating the subject area to which it belongs. Discount codes are published by DfE.	Please see the GOV.UK website*
Regulated Qualifications Framework (RQF) codes	Each qualification title is allocated an Ofqual Regulated Qualifications Framework (RQF) code. The RQF code is known as a Qualification Number (QN). This is the code that features in the DfE Section 96 and on the LARA as being eligible for 16–18 and 19+ funding, and is to be used for all qualification funding purposes. The QN is the number that will appear on the student's final certification documentation.	The QN for the qualification in this publication is: 601/5301/5
Subject codes	The subject code is used by centres to enter students for a qualification. Centres will need to use the entry codes only when claiming students' qualifications.	Advanced GCE – 9BI0
Paper code	These codes are provided for reference purposes. Students do not need to be entered for individual papers.	Paper 1: 9BI0/01 Paper 2: 9BI0/02 Paper 3: 9BI0/03 Science Practical Endorsement: 9BI0/04

*www.gov.uk/government/publications/key-stage-4-qualifications-discount-codes-and-point-scores

Appendix 4: Practical competency authentication sheet

For students to gain the Science Practical Endorsement, centres will need to:

- ensure that there is evidence that students have completed the necessary practical activities, meeting the requirements of *Appendix 5c*,
- ensure that there is evidence that students have met the requirements of each of the CPAC statements, in accordance with the guidelines provided for achieving the 'pass' standard, - complete an authentication sheet for their students.

Centres will also need to have had a satisfactory monitoring visit, according to the guidelines for monitoring visits, as set down by the JCQ.

Evidence for meeting practical attendance and CPAC competency may be provided in a variety of formats using student lab books or practical portfolios; and registers or tracking spreadsheets.

A final version of the authentication statement will be made available to schools in time for the first submission of entries in 2017.

Appendix 5: Working scientifically

Appendices 5, 5a, 5b and *5c* are taken from the document *GCE AS and A level regulatory requirements for biology, chemistry, physics and psychology* published by the DfE April 2014. Working scientifically is achieved through practical activities.

Specifications in biology, chemistry and physics must encourage the development of the skills, knowledge and understanding in science through teaching and learning opportunities for regular hands-on practical work.

In order to develop the necessary skills, knowledge and understanding, students studying biology, chemistry and physics will be required to have carried out a minimum of 12 practical activities, which will contribute towards the Practical Endorsement. These skills, knowledge and understanding will also be assessed in written examinations in the context of these, and other, practical activities.

The skills can be split into those which can be assessed through written examinations (*Appendix 5a*); and those that will be assessed by teachers through appropriate practical activities (*Appendix 5b*).

The practical activities highlighted as the minimum requirement within specifications must cover the use of apparatus and practical techniques identified for each science (*Appendix 5c*).

Appendix 5a: Practical skills identified for indirect assessment and developed through teaching and learning

Question papers will assess the student's following abilities:

a) Independent thinking

- solve problems set in practical contexts
- apply scientific knowledge to practical contexts.

b) Use and application of scientific methods and practices

- comment on experimental design and evaluate scientific methods
- present data in appropriate ways
- evaluate results and draw conclusions with reference to measurement uncertainties and errors
- identify variables including those that must be controlled.

c) Numeracy and the application of mathematical concepts in a practical context

- plot and interpret graphs
- process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science
- consider margins of error, accuracy and precision of data.

d) Instruments and equipment

- 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.

Appendix 5b: Practical skills identified for direct assessment and developed through teaching and learning

Practical work carried out throughout the course will enable students to develop the following skills:

a) Independent thinking

- apply investigative approaches and methods to practical work.

b) Use and apply scientific methods and practices

- safely and correctly use a range of practical equipment and materials
- follow written instructions
- make and record observations
- keep appropriate records of experimental activities
- present information and data in a scientific way
- use appropriate software and tools to process data, carry out research and report findings.

c) Research and referencing

- use online and offline research skills including websites, textbooks and other printed scientific sources of information
- correctly cite sources of information.

d) Instruments and equipment

- use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification.

Appendix 5c: Use of apparatus and techniques

Use of apparatus and techniques – biology

Specifications for biology must give students opportunities to use relevant apparatus to develop and demonstrate these techniques.

All of the techniques listed below will be assessed through a minimum of 16 identified practical activities within each specification. These 'core' practicals must allow students to demonstrate all of the practical skills given in *Appendix 5b*.

Practical techniques to be completed by candidates.

1. use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)
2. use appropriate instrumentation to record quantitative measurements, such as a colorimeter or potometer
3. use laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions
4. use of light microscope at high power and low power, including use of a graticule
5. produce scientific drawing from observation with annotations
6. use qualitative reagents to identify biological molecules
7. separate biological compounds using thin layer/paper chromatography or electrophoresis
8. safely and ethically use organisms to measure:
   - plant or animal responses
   - physiological functions
9. use microbiological aseptic techniques, including the use of agar plates and broth
10. safely use instruments for dissection of an animal organ, or plant organ
11. use sampling techniques in fieldwork
12. use ICT such as computer modelling, or data logger to collect data, or use software to process data.

Appendix 5d: Mapping between Appendix 5c and core practicals (biology)

This qualification gives students opportunities to use relevant apparatus to develop practical skills and demonstrate competency in a range of practical techniques.

All of the techniques listed in *Appendix 5c* will be assessed through a series of core practical activities within this specification.

To achieve the Science Practical Endorsement, students need to show competence in the 12 practical techniques listed in *Appendix 5c: Use of apparatus and techniques*.

The following table shows how each core practical activity, listed in the content, maps to the required practical techniques in *Appendix 5c: Use of apparatus and techniques*.

Biology B Core Practical	Practical technique in *Appendix 5c*											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1: Investigate a factor affecting the initial rate of an enzyme controlled reaction.	✓	✓	✓			✓		✓				✓
2: Use of the light microscope, including simple stage and eyepiece micrometers and drawing small numbers of cells from a specialised tissue.				✓	✓							
3: Make a temporary squash preparation of a root tip to show stages of mitosis in the meristem under the light microscope.			✓	✓	✓	✓		✓		✓		
4: Investigate the effect of sucrose concentrations on pollen tube growth.	✓	✓	✓	✓	✓			✓				
5: Investigate the effect of temperature on beetroot membrane permeability.	✓	✓	✓		✓			✓				
6: Determine the water potential of plant cells.	✓	✓	✓		✓			✓				
7: Dissect an insect to show the structure of the gas exchange system.				✓	✓					✓		
8: Investigate factors affecting water uptake by plant shoots using a potometer.	✓	✓	✓					✓				
9: Investigate factors affecting the rate of respiration using a respirometer.	✓	✓	✓					✓				✓
10: Investigate the effects of different wavelengths of light on the rate of photosynthesis.	✓		✓					✓				
11: Investigate the presence of different chloroplast pigments using chromatography.	✓		✓				✓	✓				
12: Investigate the rate of growth of bacteria in liquid culture.	✓		✓					✓	✓			

Biology B Core Practical	Practical technique in *Appendix 5c*											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
13: Isolate individual species from a mixed culture of bacteria using streak plating.			✓						✓			
14: Investigate the effect of gibberellin on the production of amylase in germinating cereals using a starch agar assay.	✓		✓			✓		✓	✓			
15: Investigate the effect of different sampling methods on estimates of the size of a population.	✓				✓						✓	
16: Investigate the effect of one abiotic factor on the distribution or morphology of one species.					✓			✓			✓	✓

Appendix 6: Mathematical skills and exemplifications

The information in this appendix has been taken directly from the document *GCE AS and A level regulatory requirements for biology, chemistry, physics and psychology* published by the Department for Education (April 2014).

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

The assessment of quantitative skills will include at least 10% Level 2 or above mathematical skills for biology and psychology, 20% for chemistry and 40% for physics. These skills will be applied in the context of the relevant science A Level.

All mathematical content must be assessed within the lifetime of the specification.

The following tables illustrate where these mathematical skills may be developed and could be assessed in each of the sciences. 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 in other areas of specification content.

	Mathematical skills	Exemplification of mathematical skill in the context of A Level biology (assessment is not limited to the examples given below)
(i) A.0 — arithmetic and numerical computation		
A.0.1	Recognise and make use of appropriate units in calculations	Candidates may be tested on their ability to: • convert between units, e.g. mm^3 to cm^3 as part of volumetric calculations • work out the unit for a rate, e.g. breathing rate
A.0.2	Recognise and use expressions in decimal and standard form	Candidates may be tested on their ability to: • use an appropriate number of decimal places in calculations, e.g. for a mean • carry out calculations using numbers in standard and ordinary form, e.g. use of magnification • understand standard form when applied to areas such as size of organelles • convert between numbers in standard and ordinary form • understand that significant figures need retaining when making conversions between standard and ordinary form, e.g. 0.0050 mol dm^{-3} is equivalent to 5.0×10^{-3} mol dm^{-3}
A.0.3	Use ratios, fractions and percentages	Candidates may be tested on their ability to: • calculate percentage yields • calculate surface area to volume ratio • use scales for measuring • represent phenotypic (monohybrid and dihybrid crosses)
A.0.4	Estimate results	Candidates may be tested on their ability to: • estimate results to sense check that the calculated values are appropriate
A.0.5	**Use calculators to find and use power, exponential and logarithmic functions**	**Candidates may be tested on their ability to:** • **estimate the number of bacteria grown over a certain length of time**

	Mathematical skills	Exemplification of mathematical skill in the context of A Level biology (assessment is not limited to the examples given below)
(ii) A.1 — handling data		
A.1.1	Use an appropriate number of significant figures	Candidates 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 be reported only to the limits of the least accurate measurement
A.1.2	Find arithmetic means	Candidates may be tested on their ability to: • find the mean of a range of data, e.g. the mean number of stomata in the leaves of a plant
A.1.3	Construct and interpret frequency tables and diagrams, bar charts and histograms	Candidates may be tested on their ability to: • represent a range of data in a table with clear headings, units and consistent decimal places • interpret data from a variety of tables, e.g. data relating to organ function • plot a range of data in an appropriate format, e.g. enzyme activity over time represented on a graph • interpret data for a variety of graphs, e.g. explain electrocardiogram traces
A.1.4	Understand simple probability	Candidates may be tested on their ability to: • use the terms probability and chance appropriately • understand the probability associated with genetic inheritance
A.1.5	Understand the principles of sampling as applied to scientific data	Candidates may be tested on their ability to: • analyse random data collected by an appropriate means, e.g. calculate an index of diversity to compare the biodiversity of a habitat
A.1.6	Understand the terms mean, median and mode	Candidates may be tested on their ability to: • calculate or compare the mean, median and mode of a set of data, e.g. height/mass/size of a group of organisms

	Mathematical skills	Exemplification of mathematical skill in the context of A Level biology (assessment is not limited to the examples given below)
(ii) A.1 — handling data		
A.1.7	Use a scatter diagram to identify a correlation between two variables	Candidates may be tested on their ability to: • interpret a scattergram, e.g. the effect of life style factors on health
A.1.8	Make order of magnitude calculations	Candidates may be tested on their ability to: • use and manipulate the magnification formula magnification = $\frac{\text{size of image}}{\text{size of real object}}$
A.1.9	Select and use a statistical test	Candidates 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
A.1.10	Understand measures of dispersion, including standard deviation and range	Candidates may be tested on their ability to: • calculate the standard deviation • understand why standard deviation might be a more useful measure of dispersion for a given set of data, e.g. where there is an outlying result
A.1.11	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	Candidates may be tested on their ability to: • calculate percentage error where there are uncertainties in measurement
(iii) A.2 – algebra		
A.2.1	Understand and use the symbols: =, <, <<, >>, >, ∝, ~	No exemplification required
A.2.2	Change the subject of an equation	Candidates may be tested on their ability to: • use and manipulate equations, e.g. magnification
A.2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Candidates may be tested on their ability to: • use a given equation e.g. a formula to calculate an index of diversity $D = \frac{N(N-1)}{\Sigma n(n-1)}$

	Mathematical skills	Exemplification of mathematical skill in the context of A Level biology (assessment is not limited to the examples given below)
A.2.4	Solve algebraic equations	Candidates may be tested on their ability to: • solve equations in a biological context, e.g. cardiac output = stroke volume x heart rate
A.2.5	**Use logarithms in relation to quantities that range over several orders of magnitude**	**Candidates may be tested on their ability to:** • **use a logarithmic scale in the context of microbiology, e.g. growth rate of a microorganism such as yeast**
(iv) A.3 – graphs		
A.3.1	Translate information between graphical, numerical and algebraic forms	Candidates may be tested on their ability to: • understand that data may be presented in a number of formats and be able to use these data, e.g. dissociation curves
A.3.2	Plot two variables from experimental or other data	Candidates may be tested on their ability to: • select an appropriate format for presenting data, bar charts, histograms, graphs and scattergrams
A.3.3	Understand that $y = mx + c$ represents a linear relationship	Candidates may be tested on their ability to: • predict/sketch the shape of a graph with a linear relationship, e.g. the effect of substrate concentration on the rate of an enzyme-controlled reaction with excess enzyme
A.3.4	**Determine the intercept of a graph**	**Candidates may be tested on their ability to:** • **read off an intercept point from a graph, e.g. compensation point in plants**
A.3.5	Calculate rate of change from a graph showing a linear relationship	Candidates may be tested on their ability to: • calculate a rate from a graph, e.g. rate of transpiration
A.3.6	Draw and use the slope of a tangent to a curve as a measure of rate of change	Candidates may be tested on their ability to: • use this method to measure the gradient of a point on a curve, e.g. amount of product formed plotted against time when the concentration of enzyme is fixed

	Mathematical skills	Exemplification of mathematical skill in the context of A Level biology (assessment is not limited to the examples given below)
(v) A.4 — geometry and trigonometry		
A.4.1	Calculate the circumferences, surface areas and volumes of regular shapes	Candidates may be tested on their ability to: • calculate the circumference and area of a circle • calculate the surface area and volume of rectangular prisms, of cylindrical prisms and of spheres • e.g. calculate the surface area or volume of a cell

Appendix 7: Command words used in examination papers

The following table lists the command words used in the external assessments.

Command word	Definition
Add/Label	Requires the addition or labelling to a stimulus material given in the question, for example labelling a diagram or adding units to a table.
Assess	Give careful consideration to all the factors or events that apply and identify which are the most important or relevant. Make a judgement on the importance of something, and come to a conclusion where needed.
Calculate	Obtain a numerical answer, showing relevant working. If the answer has a unit, this must be included.
Comment on	Requires the synthesis of a number of variables from data/information to form a judgement.
Compare and contrast	Looking for the similarities **and** differences of two (or more) things. Should not require the drawing of a conclusion. Answer must relate to both (or all) things mentioned in the question. The answer must include at least one similarity and one difference.
Complete	Requires the completion of a table/diagram.
Criticise	Inspect a set of data, an experimental plan or a scientific statement and consider the elements. Look at the merits and faults of the information presented and support judgements made by giving evidence.
Deduce	Draw/reach conclusion(s) from the information provided.
Describe	To give an account of something. Statements in the response need to be developed as they are often linked but do not need to include a justification or reason.
Determine	The answer must have an element which is quantitative from the stimulus provided, or must show how the answer can be reached quantitatively. To gain maximum marks there must be a quantitative element to the answer.
Devise	Plan or invent a procedure from existing principles/ideas.

Command word	Definition
Discuss	• Identify the issue/situation/problem/argument that is being assessed within the question • Explore all aspects of an issue/situation/problem/argument • Investigate the issue/situation etc by reasoning or argument
Draw	Produce a diagram either using a ruler or using freehand.
Evaluate	Review information then bring it together to form a conclusion, drawing on evidence including strengths, weaknesses, alternative actions, relevant data or information. Come to a supported judgement of a subject's qualities and relation to its context.
Explain	An explanation requires a justification/exemplification of a point. The answer must contain some element of reasoning/justification, this can include mathematical explanations.
Give/State/Name	All of these command words are really synonyms. They generally all require recall of one or more pieces of information.
Give a reason/reasons	When a statement has been made and the requirement is only to give the reasons why.
Identify	Usually requires some key information to be selected from a given stimulus/resource.
Justify	Give evidence to support (either the statement given in the question or an earlier answer)
Plot	Produce a graph by marking points accurately on a grid from data that is provided and then drawing a line of best fit through these points. A suitable scale and appropriately labelled axes must be included if these are not provided in the question.
Predict	Give an expected result.
Show that	Verify the statement given in the question.
Sketch	Produce a freehand drawing. For a graph this would need a line and labelled axis with important features indicated, the axis are not scaled.
State what is meant by	When the meaning of a term is expected but there are different ways of how these can be described.
Write	When the questions ask for an equation.

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