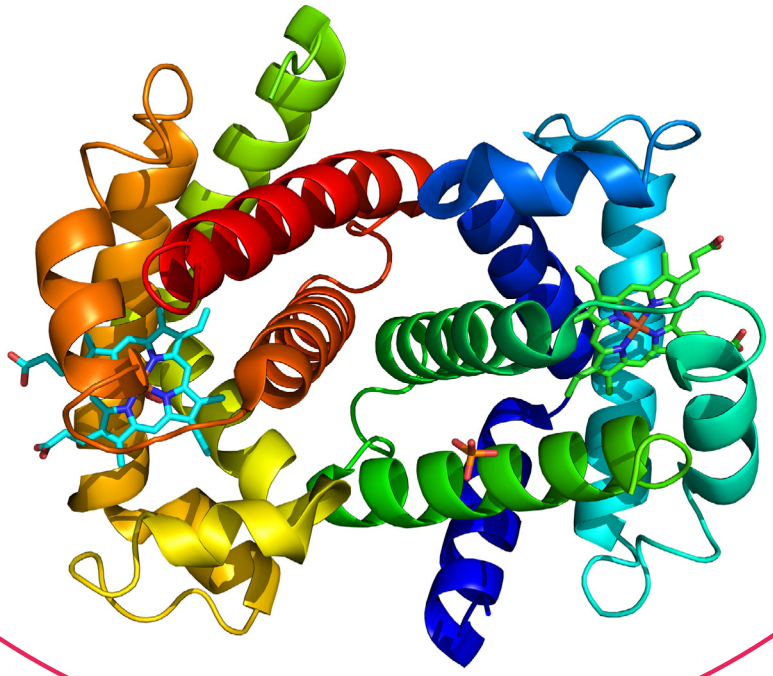
Cambridge Assessment International Education

Syllabus

Cambridge International AS & A Level Biology 9700

Use this syllabus for exams in 2025, 2026 and 2027.
Exams are available in the June and November series.
Also available for examination in March 2025, 2026 and 2027 for India.



Version 2

For the purposes of screen readers, any mention in this document of Cambridge IGCSE refers to Cambridge International General Certificate of Secondary Education.

Cambridge Pathway

Why choose Cambridge International?

Cambridge International prepares school students for life, helping them develop an informed curiosity and a lasting passion for learning. We are part of Cambridge University Press & Assessment, which is a department of the University of Cambridge.

Our Cambridge Pathway gives students a clear path for educational success from age 5 to 19. Schools can shape the curriculum around how they want students to learn – with a wide range of subjects and flexible ways to offer them. It helps students discover new abilities and a wider world, and gives them the skills they need for life, so they can achieve at school, university and work.

Our programmes and qualifications set the global standard for international education. They are created by subject experts, rooted in academic rigour and reflect the latest educational research. They provide a strong platform for students to progress from one stage to the next, and are well supported by teaching and learning resources.

We review all our syllabuses regularly, so they reflect the latest research evidence and professional teaching practice – and take account of the different national contexts in which they are taught.

We consult with teachers to help us design each syllabus around the needs of their learners. Consulting with leading universities has helped us make sure our syllabuses encourage students to master the key concepts in the subject and develop the skills necessary for success in higher education.

Our mission is to provide educational benefit through provision of international programmes and qualifications for school education and to be the world leader in this field. Together with schools, we develop Cambridge learners who are confident, responsible, reflective, innovative and engaged – equipped for success in the modern world.

Every year, nearly a million Cambridge students from 10 000 schools in 160 countries prepare for their future with the Cambridge Pathway.

School feedback: 'We think the Cambridge curriculum is superb preparation for university.'

Feedback from: Christoph Guttentag, Dean of Undergraduate Admissions, Duke University, USA

Quality management

Cambridge International is committed to providing exceptional quality. In line with this commitment, our quality management system for the provision of international qualifications and education programmes for students aged 5 to 19 is independently certified as meeting the internationally recognised standard, ISO 9001:2015. Learn more at **www.cambridgeinternational.org/ISO9001**

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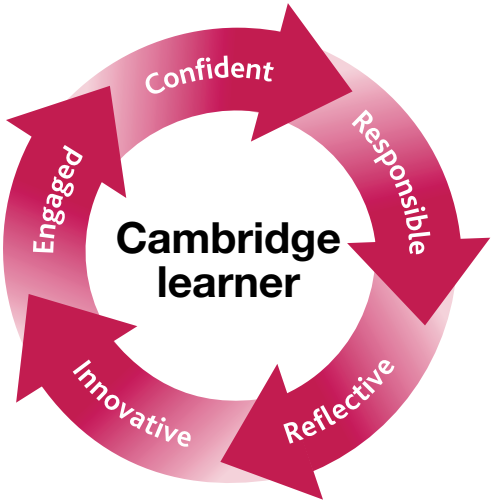
Important: Changes to this syllabus

For information about changes to this syllabus for 2025, 2026 and 2027, go to page 72.

1 Why choose this syllabus?

Key benefits

The best motivation for a student is a real passion for the subject they're learning. By offering students a variety of Cambridge International AS & A Levels, you can give them the greatest chance of finding the path of education they most want to follow. With over 50 subjects to choose from, students can select the ones they love and that they're best at, which helps motivate them throughout their studies.



Following a Cambridge International AS & A Level programme helps students develop abilities which universities value highly, including:

- a deep understanding of their subjects
- higher order thinking skills – analysis, critical thinking, problem solving
- presenting ordered and coherent arguments
- independent learning and research.

Cambridge International AS & A Level Biology develops a set of transferable skills including handling data, practical problem-solving, and applying the scientific method. Learners develop relevant attitudes, such as concern for accuracy and precision, objectivity, integrity, enquiry, initiative and inventiveness. They acquire the essential scientific skills required for progression to further studies or employment.

Our approach in Cambridge International AS & A Level Biology encourages learners to be:

confident, secure in their knowledge, keen to explore further and able to communicate effectively through the language of science

responsible, developing efficient and safe scientific practices and working collaboratively with others

reflective, able to evaluate evidence to draw informed and appropriate conclusions and recognising that the applications of science have the potential to affect the individual, the community and the environment

innovative, applying problem-solving skills to novel situations and engaging with new tools and techniques, including information technology, to develop successful approaches

engaged, developing an enquiring mind, keen to apply scientific skills in everyday life.

School feedback: 'Cambridge students develop a deep understanding of subjects and independent thinking skills.'

Feedback from: Principal, Rockledge High School, USA

Key concepts

Key concepts are essential ideas that help students develop a deep understanding of their subject and make links between different aspects. Key concepts may open up new ways of thinking about, understanding or interpreting the important things to be learned.

Good teaching and learning will incorporate and reinforce a subject's key concepts to help students gain:

- a greater depth as well as breadth of subject knowledge
- confidence, especially in applying knowledge and skills in new situations
- the vocabulary to discuss their subject conceptually and show how different aspects link together
- a level of mastery of their subject to help them enter higher education.

The key concepts identified below, carefully introduced and developed, will help to underpin the course you will teach. You may identify additional key concepts which will also enrich teaching and learning.

The key concepts for Cambridge International AS & A Level Biology are:

- **Cells as the units of life**
  A cell is the basic unit of life and all organisms are composed of one or more cells. There are two fundamental types of cell: prokaryotic and eukaryotic. Understanding how cells work provides an insight into the fundamental processes of all living organisms.
- **Biochemical processes**
  Cells are dynamic structures within which the chemistry of life takes place. Biochemistry and molecular biology help to explain how and why cells function as they do.
- **DNA, the molecule of heredity**
  Cells contain the molecule of heredity, DNA. DNA is essential for the continuity and evolution of life by allowing genetic information to be stored accurately, to be copied to daughter cells, to be passed from one generation to the next and for the controlled production of proteins. Rare errors in the accurate copying of DNA known as mutations result in genetic variation and are essential for evolution.
- **Natural selection**
  Natural selection acts on genetic variation and is the major mechanism in evolution, including speciation. Natural selection results in the accumulation of beneficial genetic mutations within populations and explains how populations can adapt to meet the demands of changing environments.
- **Organisms in their environment**
  All organisms interact with their biotic and abiotic environment. Studying these interactions allows biologists to understand better the effect of human activities on ecosystems, to develop more effective strategies to conserve biodiversity and to predict more accurately the future implications for humans of changes in the natural world.
- **Observation and experiment**
  The different fields of biology are intertwined and cannot be studied in isolation. Observation, enquiry, experimentation and fieldwork are fundamental to biology, allowing relevant evidence to be collected and considered as a basis on which to build new models and theories. Such models and theories are further tested by experimentation and observation in a cyclical process of feedback and refinement, allowing the development of robust and evidence-based conceptual understandings.

International recognition and acceptance

Our expertise in curriculum, teaching and learning, and assessment is the basis for the recognition of our programmes and qualifications around the world. Every year thousands of students with Cambridge International AS & A Levels gain places at leading universities worldwide. Our programmes and qualifications are valued by top universities around the world including those in the UK, US (including Ivy League universities), Europe, Australia, Canada and New Zealand.

UK NARIC*, the national agency in the UK for the recognition and comparison of international qualifications and skills, has carried out an independent benchmarking study of Cambridge International AS & A Level and found it to be comparable to the standard of AS & A Level in the UK. This means students can be confident that their Cambridge International AS & A Level qualifications are accepted as equivalent, grade for grade, to UK AS & A Levels by leading universities worldwide.

Cambridge International AS Level Biology makes up the first half of the Cambridge International A Level course in biology and provides a foundation for the study of biology at Cambridge International A Level. Depending on local university entrance requirements, students may be able to use it to progress directly to university courses in biology or some other subjects. It is also suitable as part of a course of general education.

Cambridge International A Level Biology provides a foundation for the study of biology or related courses in higher education. Equally it is suitable as part of a course of general education.

For more information about the relationship between the Cambridge International AS Level and Cambridge International A Level see the 'Assessment overview' section of the Syllabus overview.

We recommend learners check the Cambridge recognition database and university websites to find the most up-to-date entry requirements for courses they wish to study.

* Due to the United Kingdom leaving the European Union, the UK NARIC national recognition agency function was re-titled as UK ENIC on 1 March 2021, operated and managed by Ecctis Limited. From 1 March 2021, international benchmarking findings are published under the Ecctis name.

Learn more at **www.cambridgeinternational.org/recognition**

School feedback: 'The depth of knowledge displayed by the best A Level students makes them prime targets for America's Ivy League universities.'

Feedback from: Yale University, USA

Supporting teachers

We provide a wide range of resources, detailed guidance, innovative training and professional development so that you can give your students the best possible preparation for Cambridge International AS & A Level. To find out which resources are available for each syllabus go to **www.cambridgeinternational.org/support**

The School Support Hub is our secure online site for Cambridge teachers where you can find the resources you need to deliver our programmes. You can also keep up to date with your subject and the global Cambridge community through our online discussion forums.

Find out more at **www.cambridgeinternational.org/support**

Support for Cambridge International AS & A Level			
Planning and preparation • Schemes of work • Specimen papers • Syllabuses • Teacher guides	**Teaching and assessment** • Endorsed resources • Online forums • Support for coursework and speaking tests	**Learning and revision** • Example candidate responses • Past papers and mark schemes • Specimen paper answers	**Results** • Candidate Results Service • Principal examiner reports for teachers

Sign up for email notifications about changes to syllabuses, including new and revised products and services at **www.cambridgeinternational.org/syllabusupdates**

Professional development

We support teachers through:

- Introductory Training – face-to-face or online
- Extension Training – face-to-face or online
- Enrichment Professional Development – face-to-face or online

Find out more at **www.cambridgeinternational.org/events**

- Cambridge Professional Development Qualifications

Find out more at **www.cambridgeinternational.org/profdev**

Supporting exams officers

We provide comprehensive support and guidance for all Cambridge exams officers.
Find out more at: **www.cambridgeinternational.org/eoguide**

2 Syllabus overview

Aims

The aims describe the purposes of a course based on this syllabus.

The aims are to enable students to:

- acquire knowledge and understanding and develop practical skills, including efficient, accurate and safe scientific practices
- learn to apply the scientific method, while developing an awareness of the limitations of scientific theories and models
- develop skills in data analysis, evaluation and drawing conclusions, cultivating attitudes relevant to science such as objectivity, integrity, enquiry, initiative and inventiveness
- develop effective scientific communication skills, using appropriate terminology and scientific conventions
- understand their responsibility to others/society and to care for the environment
- enjoy science and develop an informed interest in the subject that may lead to further study.

Cambridge Assessment International Education is an education organisation and politically neutral. The contents of this syllabus, examination papers and associated materials do not endorse any political view. We endeavour to treat all aspects of the exam process neutrally.

Content overview

Candidates for Cambridge International AS Level Biology study the following topics:

1 Cell structure
2 Biological molecules
3 Enzymes
4 Cell membranes and transport
5 The mitotic cell cycle
6 Nucleic acids and protein synthesis
7 Transport in plants
8 Transport in mammals
9 Gas exchange
10 Infectious diseases
11 Immunity

AS Level candidates also study practical skills.

Candidates for Cambridge International A Level Biology study the AS topics **and** the following topics:

12 Energy and respiration
13 Photosynthesis
14 Homeostasis
15 Control and coordination
16 Inheritance
17 Selection and evolution
18 Classification, biodiversity and conservation
19 Genetic technology

A Level candidates also study practical skills.

School feedback: 'Cambridge International AS & A Levels prepare students well for university because they've learnt to go into a subject in considerable depth. There's that ability to really understand the depth and richness and the detail of a subject. It's a wonderful preparation for what they are going to face at university.'

Feedback from: US Higher Education Advisory Council

Assessment overview

Paper 1

Multiple Choice 1 hour 15 minutes

40 marks

40 Multiple-choice questions

Questions are based on the AS Level syllabus content.

Externally assessed

31% of the AS Level

15.5% of the A Level

Paper 2

AS Level Structured Questions 1 hour 15 minutes

60 marks

Structured questions

Questions are based on the AS Level syllabus content.

Externally assessed

46% of the AS Level

23% of the A Level

Paper 3

Advanced Practical Skills 2 hours

40 marks

Practical work and structured questions

Questions are based on the practical skills in the Practical assessment section of the syllabus.

The context of the questions may be outside the syllabus content.

Externally assessed

23% of the AS Level

11.5% of the A Level

Paper 4

A Level Structured Questions 2 hours

100 marks

Structured questions

Questions are based on the A Level syllabus content; knowledge of material from the AS Level syllabus content will be required.

Externally assessed

38.5% of the A Level

Paper 5

Planning, Analysis and Evaluation 1 hour 15 minutes

30 marks

Questions are based on the practical skills of planning, analysis and evaluation.

The context of the questions may be outside the syllabus content.

Externally assessed

11.5% of the A Level

Information on availability is in the **Before you start** section.

There are three routes for Cambridge International AS & A Level Biology:

	Route	Paper 1	Paper 2	Paper 3	Paper 4	Paper 5
1	**AS Level only** (Candidates take all AS components in the same exam series)	yes	yes	yes		
2	**A Level** (staged over two years) Year 1 AS Level*	yes	yes	yes		
	Year 2 Complete the A Level				yes	yes
3	**A Level** (Candidates take all components in the same exam series)	yes	yes	yes	yes	yes

* Candidates carry forward their AS Level result subject to the rules and time limits described in the *Cambridge Handbook*. See **Making entries** for more information on carry forward of results.

Candidates following an AS Level route will be eligible for grades a–e. Candidates following an A Level route are eligible for grades A*–E.

Assessment objectives

The assessment objectives (AOs) are:

AO1 Knowledge and understanding

Candidates should be able to demonstrate knowledge and understanding of:

- scientific phenomena, facts, laws, definitions, concepts and theories
- scientific vocabulary, terminology and conventions (including symbols, quantities and units)
- scientific instruments and apparatus, including techniques of operation and aspects of safety
- scientific quantities and their determination
- scientific and technological applications with their social, economic and environmental implications.

AO2 Handling, applying and evaluating information

Candidates should be able to handle, apply and evaluate information, in words or using other forms of presentation (e.g. symbols, graphical or numerical) to:

- locate, select, organise and present information from a variety of sources
- translate information from one form to another
- manipulate numerical and other data
- use information to identify patterns, report trends and draw conclusions
- give reasoned explanations for phenomena, patterns and relationships
- make predictions and construct arguments to support hypotheses
- apply knowledge, including principles, to new situations
- evaluate information and hypotheses
- demonstrate an awareness of the limitations of biological theories and models
- solve problems.

AO3 Experimental skills and investigations

Candidates should be able to:

- plan experiments and investigations
- collect, record and present observations, measurements and estimates
- analyse and interpret experimental data to reach conclusions
- evaluate methods and quality of experimental data and suggest possible improvements to experiments.

Weighting for assessment objectives

The approximate weightings allocated to each of the assessment objectives (AOs) are summarised below.

Assessment objectives as a percentage of each qualification

Assessment objective	Weighting in AS Level %	Weighting in A Level %
AO1 Knowledge and understanding	40	40
AO2 Handling, applying and evaluating information	40	40
AO3 Experimental skills and investigations	20	20
Total	100	100

Assessment objectives as a percentage of each component

Assessment objective	Weighting in components %				
	Paper 1	Paper 2	Paper 3	Paper 4	Paper 5
AO1 Knowledge and understanding	50	50	0	50	0
AO2 Handling, applying and evaluating information	50	50	0	50	0
AO3 Experimental skills and investigations	0	0	100	0	100
Total	100	100	100	100	100

3 Subject content

Candidates for Cambridge International AS Level should study topics 1–11.

Candidates for Cambridge International A Level should study **all** topics.

The content of the AS Level learning outcomes are assumed knowledge for the A Level components.

Teachers should refer to the social, environmental, economic and technological aspects of biology wherever possible throughout the syllabus. Some examples are included in the syllabus and teachers should encourage learners to apply the principles of these examples to other situations introduced in the course.

Teachers should illustrate concepts and content with examples taken from a wide range of organisms.

Everything we know about biology has been learned through practical investigation. Learners also find practical work motivating and interesting, and it can help them to understand abstract theoretical concepts. Cambridge International expects that practical activities will underpin the teaching of the whole syllabus.

The syllabus content for practical skills is in the Practical assessment section.

Teachers should ensure that candidates are prepared for the assessment of theory learning outcomes and practical skills.

This syllabus gives you the flexibility to design a course that will interest, challenge and engage your learners. Where appropriate you are responsible for selecting suitable subject contexts, resources and examples to support your learners' study. These should be appropriate for the learners' age, cultural background and learning context as well as complying with your school policies and local legal requirements.

Support for teaching practical skills for these qualifications can be found on the School Support Hub **www.cambridgeinternational.org/support**

AS Level subject content

1 Cell structure

All organisms are composed of cells. Knowledge of the structure and function of cells underpins much of biology. The fundamental differences between eukaryotic and prokaryotic cells are explored and provide useful biological background for the topic on Infectious diseases (Topic 10). Viruses are introduced as non-cellular structures, which gives candidates the opportunity to consider whether cells are the basic unit of life.

The use of light microscopes is a fundamental skill that is developed in this topic and applied throughout several other topics of the syllabus.

1.1 The microscope in cell studies

Learning outcomes
Candidates should be able to:

1. make temporary preparations of cellular material suitable for viewing with a light microscope
2. draw cells from microscope slides and photomicrographs
3. calculate magnifications of images and actual sizes of specimens from drawings, photomicrographs and electron micrographs (scanning and transmission)
4. use an eyepiece graticule and stage micrometer scale to make measurements and use the appropriate units, millimetre (mm), micrometre (μm) and nanometre (nm)
5. define resolution and magnification and explain the differences between these terms, with reference to light microscopy and electron microscopy

1.2 Cells as the basic units of living organisms

Learning outcomes
Candidates should be able to:

1. recognise organelles and other cell structures found in eukaryotic cells and outline their structures and functions, limited to:
   - cell surface membrane
   - nucleus, nuclear envelope and nucleolus
   - rough endoplasmic reticulum
   - smooth endoplasmic reticulum
   - Golgi body (Golgi apparatus or Golgi complex)
   - mitochondria (including the presence of small circular DNA)
   - ribosomes (80S in the cytoplasm and 70S in chloroplasts and mitochondria)
   - lysosomes
   - centrioles and microtubules
   - cilia
   - microvilli
   - chloroplasts (including the presence of small circular DNA)
   - cell wall
   - plasmodesmata
   - large permanent vacuole and tonoplast of plant cells

continued

1.2 Cells as the basic units of living organisms (continued)

Learning outcomes

Candidates should be able to:

2 describe and interpret photomicrographs, electron micrographs and drawings of typical plant and animal cells

3 compare the structure of typical plant and animal cells

4 state that cells use ATP from respiration for energy-requiring processes

5 outline key structural features of a prokaryotic cell as found in a typical bacterium, including:

- unicellular
- generally 1–5 μm diameter
- peptidoglycan cell walls
- circular DNA
- 70S ribosomes
- absence of organelles surrounded by double membranes

6 compare the structure of a prokaryotic cell as found in a typical bacterium with the structures of typical eukaryotic cells in plants and animals

7 state that all viruses are non-cellular structures with a nucleic acid core (either DNA or RNA) and a capsid made of protein, and that some viruses have an outer envelope made of phospholipids

2 Biological molecules

This topic introduces carbohydrates, lipids and proteins: organic molecules that are important in cells. Nucleic acids, another class of biological molecule, are covered in Topic 6. All of these molecules are based on the versatile element carbon. This topic explains how carbohydrates, lipids and proteins, which have a great diversity of function in organisms, are assembled from smaller organic molecules such as glucose, amino acids, glycerol and fatty acids.

The emphasis in this topic is on the relationship between molecular structures and their functions. Some of these ideas are continued in other topics, for example, the functions of haemoglobin in gas transport in Transport in mammals (Topic 8), phospholipids in membranes in Cell membranes and transport (Topic 4) and antibodies in Immunity (Topic 11).

Life as we know it would not be possible without water. Understanding the properties of this extraordinary molecule is an essential part of any study of biological molecules. Some of the roles of water are in this topic, others are in Topics 4, 7, 8, 12, 13 and 14.

2.1 Testing for biological molecules

Learning outcomes
Candidates should be able to:

1. describe and carry out the Benedict's test for reducing sugars, the iodine test for starch, the emulsion test for lipids and the biuret test for proteins
2. describe and carry out a semi-quantitative Benedict's test on a reducing sugar solution by standardising the test and using the results (time to first colour change or comparison to colour standards) to estimate the concentration
3. describe and carry out a test to identify the presence of non-reducing sugars, using acid hydrolysis and Benedict's solution

2.2 Carbohydrates and lipids

Learning outcomes
Candidates should be able to:

1. describe and draw the ring forms of α-glucose and β-glucose
2. define the terms monomer, polymer, macromolecule, monosaccharide, disaccharide and polysaccharide
3. state the role of covalent bonds in joining smaller molecules together to form polymers
4. state that glucose, fructose and maltose are reducing sugars and that sucrose is a non-reducing sugar
5. describe the formation of a glycosidic bond by condensation, with reference to disaccharides, including sucrose, and polysaccharides

continued

2.2 Carbohydrates and lipids continued	**Learning outcomes** Candidates should be able to: 6 describe the breakage of a glycosidic bond in polysaccharides and disaccharides by hydrolysis, with reference to the non-reducing sugar test 7 describe the molecular structure of the polysaccharides starch (amylose and amylopectin) and glycogen and relate their structures to their functions in living organisms 8 describe the molecular structure of the polysaccharide cellulose and outline how the arrangement of cellulose molecules contributes to the function of plant cell walls 9 state that triglycerides are non-polar hydrophobic molecules and describe the molecular structure of triglycerides with reference to fatty acids (saturated and unsaturated), glycerol and the formation of ester bonds 10 relate the molecular structure of triglycerides to their functions in living organisms 11 describe the molecular structure of phospholipids with reference to their hydrophilic (polar) phosphate heads and hydrophobic (non-polar) fatty acid tails
2.3 Proteins	**Learning outcomes** Candidates should be able to: 1 describe and draw the general structure of an amino acid and the formation and breakage of a peptide bond 2 explain the meaning of the terms primary structure, secondary structure, tertiary structure and quaternary structure of proteins 3 describe the types of interaction that hold protein molecules in shape: • hydrophobic interactions • hydrogen bonding • ionic bonding • covalent bonding, including disulfide bonds 4 state that globular proteins are generally soluble and have physiological roles and fibrous proteins are generally insoluble and have structural roles 5 describe the structure of a molecule of haemoglobin as an example of a globular protein, including the formation of its quaternary structure from two alpha (α) chains (α–globin), two beta (β) chains (β–globin) and a haem group 6 relate the structure of haemoglobin to its function, including the importance of iron in the haem group 7 describe the structure of a molecule of collagen as an example of a fibrous protein, and the arrangement of collagen molecules to form collagen fibres 8 relate the structures of collagen molecules and collagen fibres to their function

2.4 Water	**Learning outcomes** Candidates should be able to: 1 explain how hydrogen bonding occurs between water molecules and relate the properties of water to its roles in living organisms, limited to solvent action, high specific heat capacity and latent heat of vaporisation

3 Enzymes

Enzymes are essential for life to exist. The mode of action of enzymes and the factors that affect their activity are explored in this topic. Prior knowledge for this topic is an understanding that an enzyme is a biological catalyst that increases the rate of a reaction and remains unchanged when the reaction is complete.

There are many opportunities in this topic for candidates to gain experience of carrying out practical investigations and analysing, interpreting and evaluating their results.

3.1 Mode of action of enzymes

Learning outcomes
Candidates should be able to:

1. state that enzymes are globular proteins that catalyse reactions inside cells (intracellular enzymes) or are secreted to catalyse reactions outside cells (extracellular enzymes)
2. explain the mode of action of enzymes in terms of an active site, enzyme–substrate complex, lowering of activation energy and enzyme specificity, including the lock-and-key hypothesis and the induced-fit hypothesis
3. investigate the progress of enzyme-catalysed reactions by measuring rates of formation of products using catalase and rates of disappearance of substrate using amylase
4. outline the use of a colorimeter for measuring the progress of enzyme-catalysed reactions that involve colour changes

3.2 Factors that affect enzyme action

Learning outcomes
Candidates should be able to:

1. investigate and explain the effects of the following factors on the rate of enzyme-catalysed reactions:
   - temperature
   - pH (using buffer solutions)
   - enzyme concentration
   - substrate concentration
   - inhibitor concentration
2. explain that the maximum rate of reaction (V_{max}) is used to derive the Michaelis–Menten constant (K_m), which is used to compare the affinity of different enzymes for their substrates
3. explain the effects of reversible inhibitors, both competitive and non-competitive, on enzyme activity
4. investigate the difference in activity between an enzyme immobilised in alginate and the same enzyme free in solution, and state the advantages of using immobilised enzymes

4 Cell membranes and transport

The fluid mosaic model, introduced in 1972, describes the way in which biological molecules are arranged to form cell membranes. The model continues to be modified as understanding improves of the ways in which substances cross membranes, how cells interact and how cells respond to signals. The model also provides the basis for our understanding of passive and active movement of molecules and ions between cells and their surroundings, cell-to-cell interactions and long-distance cell signalling.

Investigating the effects of different factors on diffusion, osmosis and membrane permeability involves an understanding of the properties of phospholipids and proteins covered in Biological molecules (Topic 2).

4.1 Fluid mosaic membranes

Learning outcomes
Candidates should be able to:

1. describe the fluid mosaic model of membrane structure with reference to the hydrophobic and hydrophilic interactions that account for the formation of the phospholipid bilayer and the arrangement of proteins
2. describe the arrangement of cholesterol, glycolipids and glycoproteins in cell surface membranes
3. describe the roles of phospholipids, cholesterol, glycolipids, proteins and glycoproteins in cell surface membranes, with reference to stability, fluidity, permeability, transport (carrier proteins and channel proteins), cell signalling (cell surface receptors) and cell recognition (cell surface antigens – see 11.1.2)
4. outline the main stages in the process of cell signalling leading to specific responses:
   - secretion of specific chemicals (ligands) from cells
   - transport of ligands to target cells
   - binding of ligands to cell surface receptors on target cells

4.2 Movement into and out of cells

Learning outcomes
Candidates should be able to:

1. describe and explain the processes of simple diffusion, facilitated diffusion, osmosis, active transport, endocytosis and exocytosis
2. investigate simple diffusion and osmosis using plant tissue and non-living materials, including dialysis (Visking) tubing and agar
3. illustrate the principle that surface area to volume ratios decrease with increasing size by calculating surface areas and volumes of simple 3-D shapes (as shown in the Mathematical requirements)
4. investigate the effect of changing surface area to volume ratio on diffusion using agar blocks of different sizes

continued

4.2 Movement into and out of cells continued	**Learning outcomes** Candidates should be able to: 5 investigate the effects of immersing plant tissues in solutions of different water potentials, using the results to estimate the water potential of the tissues 6 explain the movement of water between cells and solutions in terms of water potential and explain the different effects of the movement of water on plant cells and animal cells (knowledge of solute potential and pressure potential is not expected)

5 The mitotic cell cycle

When body cells reach a certain size they divide into two cells. Nuclear division occurs first, followed by division of the cytoplasm. The mitotic cell cycle of eukaryotes involves DNA replication followed by nuclear division. This ensures the genetic uniformity of all daughter cells.

5.1 Replication and division of nuclei and cells

Learning outcomes

Candidates should be able to:

1. describe the structure of a chromosome, limited to:
   - DNA
   - histone proteins
   - sister chromatids
   - centromere
   - telomeres
2. explain the importance of mitosis in the production of genetically identical daughter cells during:
   - growth of multicellular organisms
   - replacement of damaged or dead cells
   - repair of tissues by cell replacement
   - asexual reproduction
3. outline the mitotic cell cycle, including:
   - interphase (growth in G_1 and G_2 phases and DNA replication in S phase)
   - mitosis
   - cytokinesis
4. outline the role of telomeres in preventing the loss of genes from the ends of chromosomes during DNA replication
5. outline the role of stem cells in cell replacement and tissue repair by mitosis
6. explain how uncontrolled cell division can result in the formation of a tumour

5.2 Chromosome behaviour in mitosis

Learning outcomes

Candidates should be able to:

1. describe the behaviour of chromosomes in plant and animal cells during the mitotic cell cycle and the associated behaviour of the nuclear envelope, the cell surface membrane and the spindle (names of the main stages of mitosis are expected: prophase, metaphase, anaphase and telophase)
2. interpret photomicrographs, diagrams and microscope slides of cells in different stages of the mitotic cell cycle and identify the main stages of mitosis

6 Nucleic acids and protein synthesis

Nucleic acids have roles in the storage and retrieval of genetic information and in the use of this information to synthesise polypeptides. DNA is the molecule of heredity and is an extremely stable molecule that cells replicate with great accuracy. The genetic code explains how the sequence of nucleotides in DNA and messenger RNA (mRNA) determines the sequence of amino acids that make up a polypeptide. In eukaryotes this involves the processes of transcription in the nucleus to produce mRNA, followed by translation in the cytoplasm to produce polypeptides.

6.1 Structure of nucleic acids and replication of DNA

Learning outcomes
Candidates should be able to:

1. describe the structure of nucleotides, including the phosphorylated nucleotide ATP (structural formulae are not expected)
2. state that the bases adenine and guanine are purines with a double ring structure, and that the bases cytosine, thymine and uracil are pyrimidines with a single ring structure (structural formulae for bases are not expected)
3. describe the structure of a DNA molecule as a double helix, including:
   - the importance of complementary base pairing between the 5′ to 3′ strand and the 3′ to 5′ strand (antiparallel strands)
   - differences in hydrogen bonding between C–G and A–T base pairs
   - linking of nucleotides by phosphodiester bonds
4. describe the semi-conservative replication of DNA during the S phase of the cell cycle, including:
   - the roles of DNA polymerase and DNA ligase (knowledge of other enzymes in DNA replication in cells and different types of DNA polymerase is not expected)
   - the differences between leading strand and lagging strand replication as a consequence of DNA polymerase adding nucleotides only in a 5′ to 3′ direction
5. describe the structure of an RNA molecule, using the example of messenger RNA (mRNA)

6.2 Protein synthesis

Learning outcomes
Candidates should be able to:

1. state that a polypeptide is coded for by a gene and that a gene is a sequence of nucleotides that forms part of a DNA molecule
2. describe the principle of the universal genetic code in which different triplets of DNA bases either code for specific amino acids or correspond to start and stop codons

continued

6.2 Protein synthesis continued

Learning outcomes

Candidates should be able to:

3 describe how the information in DNA is used during transcription and translation to construct polypeptides, including the roles of:
- RNA polymerase
- messenger RNA (mRNA)
- codons
- transfer RNA (tRNA)
- anticodons
- ribosomes

4 state that the strand of a DNA molecule that is used in transcription is called the transcribed or template strand and that the other strand is called the non-transcribed strand

5 explain that, in eukaryotes, the RNA molecule formed following transcription (primary transcript) is modified by the removal of non-coding sequences (introns) and the joining together of coding sequences (exons) to form mRNA

6 state that a gene mutation is a change in the sequence of base pairs in a DNA molecule that may result in an altered polypeptide

7 explain that a gene mutation is a result of substitution or deletion or insertion of nucleotides in DNA and outline how each of these types of mutation may affect the polypeptide produced

7 Transport in plants

Flowering plants do not have compact bodies like those of many animals. Leaves and extensive root systems spread out to obtain the light energy, carbon dioxide, mineral ions and water that plants gain from their environment to make organic molecules, such as sugars and amino acids. Transport systems in plants move substances from where they are absorbed or produced to where they are stored or used.

7.1 Structure of transport tissues

Learning outcomes
Candidates should be able to:

1. draw plan diagrams of transverse sections of stems, roots and leaves of herbaceous dicotyledonous plants from microscope slides and photomicrographs
2. describe the distribution of xylem and phloem in transverse sections of stems, roots and leaves of herbaceous dicotyledonous plants
3. draw and label xylem vessel elements, phloem sieve tube elements and companion cells from microscope slides, photomicrographs and electron micrographs
4. relate the structure of xylem vessel elements, phloem sieve tube elements and companion cells to their functions

7.2 Transport mechanisms

Learning outcomes
Candidates should be able to:

1. state that some mineral ions and organic compounds can be transported within plants dissolved in water
2. describe the transport of water from the soil to the xylem through the:
   - apoplast pathway, including reference to lignin and cellulose
   - symplast pathway, including reference to the endodermis, Casparian strip and suberin
3. explain that transpiration involves the evaporation of water from the internal surfaces of leaves followed by diffusion of water vapour to the atmosphere
4. explain how hydrogen bonding of water molecules is involved with movement of water in the xylem by cohesion-tension in transpiration pull and by adhesion to cellulose in cell walls
5. make annotated drawings of transverse sections of leaves from xerophytic plants to explain how they are adapted to reduce water loss by transpiration
6. state that assimilates dissolved in water, such as sucrose and amino acids, move from sources to sinks in phloem sieve tubes
7. explain how companion cells transfer assimilates to phloem sieve tubes, with reference to proton pumps and cotransporter proteins
8. explain mass flow in phloem sieve tubes down a hydrostatic pressure gradient from source to sink

8 Transport in mammals

As animals become larger, more complex and more active, transport systems become essential to supply nutrients to, and remove waste from, individual cells. Mammals are far more active than plants and require much greater supplies of oxygen. This is transported by haemoglobin inside red blood cells.

8.1 The circulatory system

Learning outcomes

Candidates should be able to:

1. state that the mammalian circulatory system is a closed double circulation consisting of a heart, blood and blood vessels including arteries, arterioles, capillaries, venules and veins
2. describe the functions of the main blood vessels of the pulmonary and systemic circulations, limited to pulmonary artery, pulmonary vein, aorta and vena cava
3. recognise arteries, veins and capillaries from microscope slides, photomicrographs and electron micrographs and make plan diagrams showing the structure of arteries and veins in transverse section (TS) and longitudinal section (LS)
4. explain how the structure of muscular arteries, elastic arteries, veins and capillaries are each related to their functions
5. recognise and draw red blood cells, monocytes, neutrophils and lymphocytes from microscope slides, photomicrographs and electron micrographs
6. state that water is the main component of blood and tissue fluid and relate the properties of water to its role in transport in mammals, limited to solvent action and high specific heat capacity
7. state the functions of tissue fluid and describe the formation of tissue fluid in a capillary network

8.2 Transport of oxygen and carbon dioxide	**Learning outcomes** Candidates should be able to: 1 describe the role of red blood cells in transporting oxygen and carbon dioxide with reference to the roles of: • haemoglobin • carbonic anhydrase • the formation of haemoglobinic acid • the formation of carbaminohaemoglobin 2 describe the chloride shift and explain the importance of the chloride shift 3 describe the role of plasma in the transport of carbon dioxide 4 describe and explain the oxygen dissociation curve of adult haemoglobin 5 explain the importance of the oxygen dissociation curve at partial pressures of oxygen in the lungs and in respiring tissues 6 describe the Bohr shift and explain the importance of the Bohr shift
8.3 The heart	**Learning outcomes** Candidates should be able to: 1 describe the external and internal structure of the mammalian heart 2 explain the differences in the thickness of the walls of the: • atria and ventricles • left ventricle and right ventricle 3 describe the cardiac cycle, with reference to the relationship between blood pressure changes during systole and diastole and the opening and closing of valves 4 explain the roles of the sinoatrial node, the atrioventricular node and the Purkyne tissue in the cardiac cycle (knowledge of nervous and hormonal control is not expected)

9 Gas exchange

The gas exchange system is responsible for the uptake of oxygen into the blood and the excretion of carbon dioxide. An understanding of this system shows how cells, tissues and organs function together to exchange these gases between the blood and the environment.

9.1 The gas exchange system

Learning outcomes

Candidates should be able to:

1. describe the structure of the human gas exchange system, limited to:
   - lungs
   - trachea
   - bronchi
   - bronchioles
   - alveoli
   - capillary network
2. describe the distribution in the gas exchange system of cartilage, ciliated epithelium, goblet cells, squamous epithelium of alveoli, smooth muscle and capillaries
3. recognise cartilage, ciliated epithelium, goblet cells, squamous epithelium of alveoli, smooth muscle and capillaries in microscope slides, photomicrographs and electron micrographs
4. recognise trachea, bronchi, bronchioles and alveoli in microscope slides, photomicrographs and electron micrographs and make plan diagrams of transverse sections of the walls of the trachea and bronchus
5. describe the functions of ciliated epithelial cells, goblet cells and mucous glands in maintaining the health of the gas exchange system
6. describe the functions in the gas exchange system of cartilage, smooth muscle, elastic fibres and squamous epithelium
7. describe gas exchange between air in the alveoli and blood in the capillaries

10 Infectious diseases

The infectious diseases studied in this topic are caused by pathogens that are transmitted from one human host to another. Some, like *Plasmodium* that causes malaria, are transmitted by vectors, but there are many other methods of transmission, such as through water and food or during sexual activity. An understanding of the biology of the pathogen and its mode of transmission is essential if the disease is to be controlled and ultimately prevented.

10.1 Infectious diseases

Learning outcomes
Candidates should be able to:

1. state that infectious diseases are caused by pathogens and are transmissible
2. state the name and type of pathogen that causes each of the following diseases:
   - cholera – caused by the bacterium *Vibrio cholerae*
   - malaria – caused by the protoctists *Plasmodium falciparum*, *Plasmodium malariae*, *Plasmodium ovale* and *Plasmodium vivax*
   - tuberculosis (TB) – caused by the bacteria *Mycobacterium tuberculosis* and *Mycobacterium bovis*
   - HIV/AIDS – caused by the human immunodeficiency virus (HIV)
3. explain how cholera, malaria, TB and HIV are transmitted
4. discuss the biological, social and economic factors that need to be considered in the prevention and control of cholera, malaria, TB and HIV (details of the life cycle of the malarial parasite are not expected)

10.2 Antibiotics

Learning outcomes
Candidates should be able to:

1. outline how penicillin acts on bacteria and why antibiotics do not affect viruses
2. discuss the consequences of antibiotic resistance and the steps that can be taken to reduce its impact

11 Immunity

An understanding of the immune system shows how cells and molecules function together to protect the body against infectious diseases and how, after an initial infection, the body is protected from subsequent infections by the same pathogen. Phagocytosis is an immediate non-specific part of the immune system, while the actions of lymphocytes provide effective defence against specific pathogens.

11.1 The immune system

Learning outcomes
Candidates should be able to:

1. describe the mode of action of phagocytes (macrophages and neutrophils)
2. explain what is meant by an antigen (see 4.1.3) and state the difference between self antigens and non-self antigens
3. describe the sequence of events that occurs during a primary immune response with reference to the roles of:
   - macrophages
   - B-lymphocytes, including plasma cells
   - T-lymphocytes, limited to T-helper cells and T-killer cells
4. explain the role of memory cells in the secondary immune response and in long-term immunity

11.2 Antibodies and vaccination

Learning outcomes
Candidates should be able to:

1. relate the molecular structure of antibodies to their functions
2. outline the hybridoma method for the production of monoclonal antibodies
3. outline the principles of using monoclonal antibodies in the diagnosis of disease and in the treatment of disease
4. describe the differences between active immunity and passive immunity and between natural immunity and artificial immunity
5. explain that vaccines contain antigens that stimulate immune responses to provide long-term immunity
6. explain how vaccination programmes can help to control the spread of infectious diseases

A Level subject content

12 Energy and respiration

Energy is a fundamental concept in biology. All living organisms require a source of cellular energy to drive their various activities. All organisms respire by using enzyme-catalysed reactions to release energy from energy-rich molecules such as glucose and fatty acids and transfer that energy to ATP. ATP is the universal energy currency of cells. In eukaryotes, aerobic respiration occurs in mitochondria.

The practical activities in this topic give opportunities for candidates to plan investigations, analyse and interpret data and evaluate experimental procedures and the quality of the data collected.

12.1 Energy

Learning outcomes

Candidates should be able to:

1. outline the need for energy in living organisms, as illustrated by active transport, movement and anabolic reactions, such as those occurring in DNA replication and protein synthesis
2. describe the features of ATP that make it suitable as the universal energy currency
3. state that ATP is synthesised by:
   - transfer of phosphate in substrate-linked reactions
   - chemiosmosis in membranes of mitochondria and chloroplasts
4. explain the relative energy values of carbohydrates, lipids and proteins as respiratory substrates
5. state that the respiratory quotient (RQ) is the ratio of the number of molecules of carbon dioxide produced to the number of molecules of oxygen taken in, as a result of respiration
6. calculate RQ values of different respiratory substrates from equations for respiration
7. describe and carry out investigations, using simple respirometers, to determine the RQ of germinating seeds or small invertebrates (e.g. blowfly larvae)

12.2 Respiration

Learning outcomes

Candidates should be able to:

1 State where each of the four stages in aerobic respiration occurs in eukaryotic cells:
- glycolysis in the cytoplasm
- link reaction in the mitochondrial matrix
- Krebs cycle in the mitochondrial matrix
- oxidative phosphorylation on the inner membrane of mitochondria

2 outline glycolysis as phosphorylation of glucose and the subsequent splitting of fructose 1,6-bisphosphate (6C) into two triose phosphate molecules (3C), which are then further oxidised to pyruvate (3C), with the production of ATP and reduced NAD

3 explain that, when oxygen is available, pyruvate enters mitochondria to take part in the link reaction

4 describe the link reaction, including the role of coenzyme A in the transfer of acetyl (2C) groups

5 outline the Krebs cycle, explaining that oxaloacetate (4C) acts as an acceptor of the 2C fragment from acetyl coenzyme A to form citrate (6C), which is converted back to oxaloacetate in a series of small steps

6 explain that reactions in the Krebs cycle involve decarboxylation and dehydrogenation and the reduction of the coenzymes NAD and FAD

7 describe the role of NAD and FAD in transferring hydrogen to carriers in the inner mitochondrial membrane

8 explain that during oxidative phosphorylation:
- hydrogen atoms split into protons and energetic electrons
- energetic electrons release energy as they pass through the electron transport chain (details of carriers are not expected)
- the released energy is used to transfer protons across the inner mitochondrial membrane
- protons return to the mitochondrial matrix by facilitated diffusion through ATP synthase, providing energy for ATP synthesis (details of ATP synthase are not expected)
- oxygen acts as the final electron acceptor to form water

9 describe the relationship between the structure and function of mitochondria using diagrams and electron micrographs

10 outline respiration in anaerobic conditions in mammals (lactate fermentation) and in yeast cells (ethanol fermentation)

continued

12.2 Respiration continued	**Learning outcomes** Candidates should be able to: 11 explain why the energy yield from respiration in aerobic conditions is much greater than the energy yield from respiration in anaerobic conditions (a detailed account of the total yield of ATP from the aerobic respiration of glucose is not expected) 12 explain how rice is adapted to grow with its roots submerged in water, limited to the development of aerenchyma in roots, ethanol fermentation in roots and faster growth of stems 13 describe and carry out investigations using redox indicators, including DCPIP and methylene blue, to determine the effects of temperature and substrate concentration on the rate of respiration of yeast 14 describe and carry out investigations using simple respirometers to determine the effect of temperature on the rate of respiration

13 Photosynthesis

Photosynthesis is the energy transfer process that is the basis of nearly all life on Earth. It provides energy directly or indirectly to all the organisms in most food chains. In eukaryotes, the process occurs within chloroplasts. Candidates should apply their knowledge of plant cells from Cell structure (Topic 1) and leaf structure from Transport in plants (Topic 7) while studying photosynthesis. Various environmental factors influence the rate at which photosynthesis occurs.

The practical activities in this topic give opportunities for candidates to plan investigations, analyse and interpret data and evaluate experimental procedures and the quality of the data that they collect.

13.1 Photosynthesis as an energy transfer process

Learning outcomes

Candidates should be able to:

1. describe the relationship between the structure of chloroplasts, as shown in diagrams and electron micrographs, and their function
2. explain that energy transferred as ATP and reduced NADP from the light-dependent stage is used during the light-independent stage (Calvin cycle) of photosynthesis to produce complex organic molecules
3. state that within a chloroplast, the thylakoids (thylakoid membranes and thylakoid spaces), which occur in stacks called grana, are the site of the light-dependent stage and the stroma is the site of the light-independent stage
4. describe the role of chloroplast pigments (chlorophyll *a*, chlorophyll *b*, carotene and xanthophyll) in light absorption in thylakoids
5. interpret absorption spectra of chloroplast pigments and action spectra for photosynthesis
6. describe and use chromatography to separate and identify chloroplast pigments (reference should be made to R_f values in identification of chloroplast pigments)
7. state that cyclic photophosphorylation and non-cyclic photophosphorylation occur during the light-dependent stage of photosynthesis
8. explain that in cyclic photophosphorylation:
   - only photosystem I (PSI) is involved
   - photoactivation of chlorophyll occurs
   - ATP is synthesised
9. explain that in non-cyclic photophosphorylation:
   - photosystem I (PSI) and photosystem II (PSII) are both involved
   - photoactivation of chlorophyll occurs
   - the oxygen-evolving complex catalyses the photolysis of water
   - ATP and reduced NADP are synthesised

continued

13.1	**Photosynthesis as an energy transfer process continued**	**Learning outcomes** Candidates should be able to: 10 explain that during photophosphorylation: • energetic electrons release energy as they pass through the electron transport chain (details of carriers are not expected) • the released energy is used to transfer protons across the thylakoid membrane • protons return to the stroma from the thylakoid space by facilitated diffusion through ATP synthase, providing energy for ATP synthesis (details of ATP synthase are not expected) 11 outline the three main stages of the Calvin cycle: • rubisco catalyses the fixation of carbon dioxide by combination with a molecule of ribulose bisphosphate (RuBP), a 5C compound, to yield two molecules of glycerate 3-phosphate (GP), a 3C compound • GP is reduced to triose phosphate (TP) in reactions involving reduced NADP and ATP • RuBP is regenerated from TP in reactions that use ATP 12 state that Calvin cycle intermediates are used to produce other molecules, limited to GP to produce some amino acids and TP to produce carbohydrates, lipids and amino acids
13.2	**Investigation of limiting factors**	**Learning outcomes** Candidates should be able to: 1 state that light intensity, carbon dioxide concentration and temperature are examples of limiting factors of photosynthesis 2 explain the effects of changes in light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis 3 describe and carry out investigations using redox indicators, including DCPIP and methylene blue, and a suspension of chloroplasts to determine the effects of light intensity and light wavelength on the rate of photosynthesis 4 describe and carry out investigations using whole plants, including aquatic plants, to determine the effects of light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis

14 Homeostasis

Cells function most efficiently if they are kept in near optimum conditions. Cells in multicellular animals are surrounded by tissue fluid. The composition of tissue fluid is kept constant by exchanges with the blood as discussed in the topic on Transport in mammals (Topic 8). In mammals, core temperature, blood glucose concentration and blood water potential are maintained within narrow limits to ensure the efficient operation of cells. Prior knowledge for this topic includes an understanding that waste products are excreted from the body and an outline of the structure and function of the nervous and endocrine systems. In plants, guard cells respond to fluctuations in environmental conditions and open and close stomata as appropriate for photosynthesis and conserving water.

14.1 Homeostasis in mammals

Learning outcomes

Candidates should be able to:

1. explain what is meant by homeostasis and the importance of homeostasis in mammals
2. explain the principles of homeostasis in terms of internal and external stimuli, receptors, coordination systems (nervous system and endocrine system), effectors (muscles and glands) and negative feedback
3. state that urea is produced in the liver from the deamination of excess amino acids
4. describe the structure of the human kidney, limited to:
   - fibrous capsule
   - cortex
   - medulla
   - renal pelvis
   - ureter
   - branches of the renal artery and renal vein
5. Identify, in diagrams, photomicrographs and electron micrographs, the parts of a nephron and its associated blood vessels and structures, limited to:
   - glomerulus
   - Bowman's capsule
   - proximal convoluted tubule
   - loop of Henle
   - distal convoluted tubule
   - collecting duct
6. describe and explain the formation of urine in the nephron, limited to:
   - the formation of glomerular filtrate by ultrafiltration in the Bowman's capsule
   - selective reabsorption in the proximal convoluted tubule
7. relate the detailed structure of the Bowman's capsule and proximal convoluted tubule to their functions in the formation of urine
8. describe the roles of the hypothalamus, posterior pituitary gland, antidiuretic hormone (ADH), aquaporins and collecting ducts in osmoregulation

continued

14.1 Homeostasis in mammals continued	**Learning outcomes** Candidates should be able to: 9 describe the principles of cell signalling using the example of the control of blood glucose concentration by glucagon, limited to: • binding of hormone to cell surface receptor causing conformational change • activation of G-protein leading to stimulation of adenylyl cyclase • formation of the second messenger, cyclic AMP (cAMP) • activation of protein kinase A by cAMP leading to initiation of an enzyme cascade • amplification of the signal through the enzyme cascade as a result of activation of more and more enzymes by phosphorylation • cellular response in which the final enzyme in the pathway is activated, catalysing the breakdown of glycogen 10 explain how negative feedback control mechanisms regulate blood glucose concentration, with reference to the effects of insulin on muscle cells and liver cells and the effect of glucagon on liver cells 11 explain the principles of operation of test strips and biosensors for measuring the concentration of glucose in blood and urine, with reference to glucose oxidase and peroxidase enzymes
14.2 Homeostasis in plants	**Learning outcomes** Candidates should be able to: 1 explain that stomata respond to changes in environmental conditions by opening and closing and that regulation of stomatal aperture balances the need for carbon dioxide uptake by diffusion with the need to minimise water loss by transpiration 2 explain that stomata have daily rhythms of opening and closing 3 describe the structure and function of guard cells and explain the mechanism by which they open and close stomata 4 describe the role of abscisic acid in the closure of stomata during times of water stress, including the role of calcium ions as a second messenger

15 Control and coordination

All the activities of multicellular organisms require coordinating, some very rapidly and some more slowly. The nervous system and the endocrine system provide coordination in mammals. Coordination systems also exist in plants.

15.1 Control and coordination in mammals

Learning outcomes

Candidates should be able to:

1. describe the features of the endocrine system with reference to the hormones ADH, glucagon and insulin (see 14.1.8, 14.1.9 and 14.1.10)
2. compare the features of the nervous system and the endocrine system
3. describe the structure and function of a sensory neurone and a motor neurone and state that intermediate neurones connect sensory neurones and motor neurones
4. outline the role of sensory receptor cells in detecting stimuli and stimulating the transmission of impulses in sensory neurones
5. describe the sequence of events that results in an action potential in a sensory neurone, using a chemoreceptor cell in a human taste bud as an example
6. describe and explain changes to the membrane potential of neurones, including:
   - how the resting potential is maintained
   - the events that occur during an action potential
   - how the resting potential is restored during the refractory period
7. describe and explain the rapid transmission of an impulse in a myelinated neurone with reference to saltatory conduction
8. explain the importance of the refractory period in determining the frequency of impulses
9. describe the structure of a cholinergic synapse and explain how it functions, including the role of calcium ions
10. describe the roles of neuromuscular junctions, the T-tubule system and sarcoplasmic reticulum in stimulating contraction in striated muscle
11. describe the ultrastructure of striated muscle with reference to sarcomere structure using electron micrographs and diagrams
12. explain the sliding filament model of muscular contraction including the roles of troponin, tropomyosin, calcium ions and ATP

15.2	**Control and coordination in plants**	**Learning outcomes** Candidates should be able to: 1 describe the rapid response of the Venus fly trap to stimulation of hairs on the lobes of modified leaves and explain how the closure of the trap is achieved 2 explain the role of auxin in elongation growth by stimulating proton pumping to acidify cell walls 3 describe the role of gibberellin in the germination of barley (see 16.3.4)

16 Inheritance

Genetic information is transmitted from generation to generation to maintain the continuity of life. In sexual reproduction, meiosis introduces genetic variation so that offspring resemble their parents but are not identical to them. Genetic crosses reveal how some features are inherited. The phenotype of organisms is determined partly by the genes that they have inherited and partly by the effect of the environment. Genes determine how organisms develop; gene control in bacteria gives us a glimpse of this process in action.

16.1 Passage of information from parents to offspring

Learning outcomes
Candidates should be able to:

1. explain the meanings of the terms haploid (n) and diploid (2n)
2. explain what is meant by homologous pairs of chromosomes
3. explain the need for a reduction division during meiosis in the production of gametes
4. describe the behaviour of chromosomes in plant and animal cells during meiosis and the associated behaviour of the nuclear envelope, the cell surface membrane and the spindle (names of the main stages of meiosis, but not the sub-divisions of prophase I, are expected: prophase I, metaphase I, anaphase I, telophase I, prophase II, metaphase II, anaphase II and telophase II)
5. interpret photomicrographs and diagrams of cells in different stages of meiosis and identify the main stages of meiosis
6. explain that crossing over and random orientation (independent assortment) of pairs of homologous chromosomes and sister chromatids during meiosis produces genetically different gametes
7. explain that the random fusion of gametes at fertilisation produces genetically different individuals

16.2 The roles of genes in determining the phenotype

Learning outcomes
Candidates should be able to:

1. explain the terms gene, locus, allele, dominant, recessive, codominant, linkage, test cross, F1, F2, phenotype, genotype, homozygous and heterozygous
2. interpret and construct genetic diagrams, including Punnett squares, to explain and predict the results of monohybrid crosses and dihybrid crosses that involve dominance, codominance, multiple alleles and sex linkage
3. interpret and construct genetic diagrams, including Punnett squares, to explain and predict the results of dihybrid crosses that involve autosomal linkage and epistasis (knowledge of the expected ratios for different types of epistasis is not expected)
4. interpret and construct genetic diagrams, including Punnett squares, to explain and predict the results of test crosses
5. use the chi-squared test to test the significance of differences between observed and expected results (the formula for the chi-squared test will be provided, as shown in the Mathematical requirements)

continued

16.2 The roles of genes in determining the phenotype continued	**Learning outcomes** Candidates should be able to: 6 explain the relationship between genes, proteins and phenotype with respect to the: • *TYR* gene, tyrosinase and albinism • *HBB* gene, haemoglobin and sickle cell anaemia • *F8* gene, factor VIII and haemophilia • *HTT* gene, huntingtin and Huntington's disease 7 explain the role of gibberellin in stem elongation including the role of the dominant allele, *Le*, that codes for a functional enzyme in the gibberellin synthesis pathway, and the recessive allele, *le*, that codes for a non-functional enzyme
16.3 Gene control	**Learning outcomes** Candidates should be able to: 1 describe the differences between structural genes and regulatory genes and the differences between repressible enzymes and inducible enzymes 2 explain genetic control of protein production in a prokaryote using the *lac* operon (knowledge of the role of cAMP is not expected) 3 state that transcription factors are proteins that bind to DNA and are involved in the control of gene expression in eukaryotes by decreasing or increasing the rate of transcription 4 explain how gibberellin activates genes by causing the breakdown of DELLA protein repressors, which normally inhibit factors that promote transcription

17 Selection and evolution

In 1858, Charles Darwin and Alfred Russel Wallace proposed a theory of natural selection to account for the evolution of species. A year later, Darwin published *On the Origin of Species*, providing evidence for the way in which aspects of the environment act as agents of selection and determine which phenotypic forms survive and which do not. The individuals best adapted to the prevailing conditions are most likely to succeed in the 'struggle for existence'.

17.1 Variation

Learning outcomes
Candidates should be able to:

1. explain, with examples, that phenotypic variation is due to genetic factors or environmental factors or a combination of genetic and environmental factors
2. explain what is meant by discontinuous variation and continuous variation
3. explain the genetic basis of discontinuous variation and continuous variation
4. use the *t*-test to compare the means of two different samples (the formula for the *t*-test will be provided, as shown in the Mathematical requirements)

17.2 Natural and artificial selection

Learning outcomes
Candidates should be able to:

1. explain that natural selection occurs because populations have the capacity to produce many offspring that compete for resources; in the 'struggle for existence', individuals that are best adapted are most likely to survive to reproduce and pass on their alleles to the next generation
2. explain how environmental factors can act as stabilising, disruptive and directional forces of natural selection
3. explain how selection, the founder effect and genetic drift, including the bottleneck effect, may affect allele frequencies in populations
4. outline how bacteria become resistant to antibiotics as an example of natural selection
5. use the Hardy–Weinberg principle to calculate allele and genotype frequencies in populations and state the conditions when this principle can be applied (the two equations for the Hardy–Weinberg principle will be provided, as shown in the Mathematical requirements)
6. describe the principles of selective breeding (artificial selection)
7. outline the following examples of selective breeding:
   - the introduction of disease resistance to varieties of wheat and rice
   - inbreeding and hybridisation to produce vigorous, uniform varieties of maize
   - improving the milk yield of dairy cattle

17.3 Evolution	**Learning outcomes** Candidates should be able to: 1 outline the theory of evolution as a process leading to the formation of new species from pre-existing species over time, as a result of changes to gene pools from generation to generation 2 discuss how DNA sequence data can show evolutionary relationships between species 3 explain how speciation may occur as a result of genetic isolation by: • geographical separation (allopatric speciation) • ecological and behavioural separation (sympatric speciation)

18 Classification, biodiversity and conservation

Classification systems attempt to order all the organisms that exist on Earth according to their characteristics and evolutionary relationships with one another. There are opportunities in this topic for candidates to observe different species in their locality and assess species distribution and abundance. Fieldwork is an important part of a biological education because it provides opportunities to appreciate and analyse biodiversity, and to study the interactions between organisms and their environment. The biodiversity of the Earth is threatened by human activities and climate change. Conserving biodiversity is a difficult task; individuals, local groups, national and international organisations can all make significant contributions. Candidates should appreciate the threats to biodiversity and consider some of the steps taken in conservation, both locally and globally.

18.1 Classification

Learning outcomes
Candidates should be able to:

1. discuss the meaning of the term species, limited to the biological species concept, morphological species concept and ecological species concept
2. describe the classification of organisms into three domains: Archaea, Bacteria and Eukarya
3. state that Archaea and Bacteria are prokaryotes and that there are differences between them, limited to differences in membrane lipids, ribosomal RNA and composition of cell walls
4. describe the classification of organisms in the Eukarya domain into the taxonomic hierarchy of kingdom, phylum, class, order, family, genus and species
5. outline the characteristic features of the kingdoms Protoctista, Fungi, Plantae and Animalia
6. outline how viruses are classified, limited to the type of nucleic acid (RNA or DNA) and whether this is single stranded or double stranded

18.2 Biodiversity

Learning outcomes
Candidates should be able to:

1. define the terms ecosystem and niche
2. explain that biodiversity can be assessed at different levels, including:
   - the number and range of different ecosystems and habitats
   - the number of species and their relative abundance
   - the genetic variation within each species
3. explain the importance of random sampling in determining the biodiversity of an area
4. describe and use suitable methods to assess the distribution and abundance of organisms in an area, limited to frame quadrats, line transects, belt transects and mark-release-recapture using the Lincoln index (the formula for the Lincoln index will be provided, as shown in the Mathematical requirements)

continued

18.2 Biodiversity continued	**Learning outcomes** Candidates should be able to: 5 use Spearman's rank correlation and Pearson's linear correlation to analyse the relationships between two variables, including how biotic and abiotic factors affect the distribution and abundance of species (the formulae for these correlations will be provided, as shown in the Mathematical requirements) 6 use Simpson's index of diversity (*D*) to calculate the biodiversity of an area, and state the significance of different values of *D* (the formula for Simpson's index of diversity will be provided, as shown in the Mathematical requirements)
18.3 Conservation	**Learning outcomes** Candidates should be able to: 1 explain why populations and species can become extinct as a result of: • climate change • competition • hunting by humans • degradation and loss of habitats 2 outline reasons for the need to maintain biodiversity 3 outline the roles of zoos, botanic gardens, conserved areas (including national parks and marine parks), 'frozen zoos' and seed banks, in the conservation of endangered species 4 describe methods of assisted reproduction used in the conservation of endangered mammals, limited to IVF, embryo transfer and surrogacy 5 explain reasons for controlling invasive alien species 6 outline the role in conservation of the International Union for Conservation of Nature (IUCN) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

19 Genetic technology

The discovery in the early 1950s of the structure of DNA by Watson and Crick, supported by the work of Franklin, Wilkins and Chargaff, and discoveries since, have led to many applications of genetic technology in areas of medicine, agriculture and forensic science. This topic relies heavily on prior knowledge of DNA and RNA structure and protein synthesis from the topic on Nucleic acids and protein synthesis (Topic 6).

Candidates will benefit from carrying out practical work using electrophoresis, either with DNA or specially prepared dyes used to represent DNA.

19.1 Principles of genetic technology

Learning outcomes
Candidates should be able to:

1. define the term recombinant DNA
2. explain that genetic engineering is the deliberate manipulation of genetic material to modify specific characteristics of an organism and that this may involve transferring a gene into an organism so that the gene is expressed
3. explain that genes to be transferred into an organism may be:
   - extracted from the DNA of a donor organism
   - synthesised from the mRNA of a donor organism
   - synthesised chemically from nucleotides
4. explain the roles of restriction endonucleases, DNA ligase, plasmids, DNA polymerase and reverse transcriptase in the transfer of a gene into an organism
5. explain why a promoter may have to be transferred into an organism as well as the desired gene
6. explain how gene expression may be confirmed by the use of marker genes coding for fluorescent products
7. explain that gene editing is a form of genetic engineering involving the insertion, deletion or replacement of DNA at specific sites in the genome
8. describe and explain the steps involved in the polymerase chain reaction (PCR) to clone and amplify DNA, including the role of *Taq* polymerase
9. describe and explain how gel electrophoresis is used to separate DNA fragments of different lengths
10. outline how microarrays are used in the analysis of genomes and in detecting mRNA in studies of gene expression
11. outline the benefits of using databases that provide information about nucleotide sequences of genes and genomes, and amino acid sequences of proteins and protein structures

19.2	**Genetic technology applied to medicine**	**Learning outcomes** Candidates should be able to: 1 explain the advantages of using recombinant human proteins to treat disease, using the examples insulin, factor VIII and adenosine deaminase 2 outline the advantages of genetic screening, using the examples of breast cancer (*BRCA1* and *BRCA2*), Huntington's disease and cystic fibrosis 3 outline how genetic diseases can be treated with gene therapy, using the examples severe combined immunodeficiency (SCID) and inherited eye diseases 4 discuss the social and ethical considerations of using genetic screening and gene therapy in medicine
19.3	**Genetically modified organisms in agriculture**	**Learning outcomes** Candidates should be able to: 1 explain that genetic engineering may help to solve the global demand for food by improving the quality and productivity of farmed animals and crop plants, using the examples of GM salmon, herbicide resistance in soybean and insect resistance in cotton 2 discuss the ethical and social implications of using genetically modified organisms (GMOs) in food production

4 Details of the assessment

Paper 1 Multiple Choice

Written paper, 1 hour 15 minutes, 40 marks

Forty multiple-choice questions of the four-choice type, testing assessment objectives AO1 and AO2.

Questions are based on the AS Level syllabus content.

Paper 2 AS Level Structured Questions

Written paper, 1 hour 15 minutes, 60 marks

Structured questions testing assessment objectives AO1 and AO2.

Questions are based on the AS Level syllabus content.

Paper 3 Advanced Practical Skills

Practical test, 2 hours, 40 marks

This paper tests assessment objective AO3 in a practical context.

Questions are based on the practical skills (including the use of a light microscope) in the Practical assessment section of the syllabus for Paper 3. The context of the questions may be outside the syllabus content.

Paper 4 A Level Structured Questions

Written paper, 2 hours, 100 marks

Structured questions testing assessment objectives AO1 and AO2.

Questions are based on the A Level syllabus content; knowledge of material from the AS Level syllabus content will be required.

Paper 5 Planning, Analysis and Evaluation

Written paper, 1 hour 15 minutes, 30 marks

Structured questions testing assessment objective AO3.

Questions are based on the practical skills of planning, analysis and evaluation in the Practical assessment section of the syllabus for Paper 5. The context of the questions may be outside the syllabus content.

Command words

Command words and their meanings help candidates know what is expected from them in the exam. The table below includes command words used in the assessment for this syllabus. The use of the command word will relate to the subject context.

Command word	What it means
Assess	make an informed judgement
Calculate	work out from given facts, figures or information
Comment	give an informed opinion
Compare	identify/comment on similarities and/or differences
Contrast	identify/comment on differences
Define	give precise meaning
Describe	state the points of a topic / give characteristics and main features
Determine	establish an answer using the information available
Discuss	write about issue(s) or topic(s) in depth in a structured way
Explain	set out purposes or reasons / make the relationships between things evident / provide why and/or how and support with relevant evidence
Give	produce an answer from a given source or recall/memory
Identify	name/select/recognise
Outline	set out main points
Predict	suggest what may happen based on available information
Sketch	make a simple drawing showing the key features
State	express in clear terms
Suggest	apply knowledge and understanding to situations where there are a range of valid responses in order to make proposals / put forward considerations

5 Practical assessment

Introduction

Teachers should ensure that learners practise practical skills throughout their course of study. As a guide, learners should spend at least 20 per cent of their time doing practical work individually or in small groups. This 20 per cent does not include the time spent observing demonstrations of experiments and simulations.

The practical work that learners do during their course should aim to:

- provide learning opportunities so that they develop the skills they need to carry out experimental and investigative work
- reinforce their learning of the theoretical subject content of the syllabus
- instil an understanding of the relationship between experimentation and theory in scientific method
- be enjoyable, contributing to the motivation of learners.

Candidates' practical skills will be assessed in Paper 3 and Paper 5. In each of these papers, the questions may be based on biology not included in the syllabus content, but candidates will be mainly assessed on their practical skills rather than their knowledge of theory. Where appropriate, candidates will be given any additional information that they need.

Paper 3 Advanced Practical Skills

Paper 3 is a timetabled, laboratory-based practical paper focusing on the practical skills of:

- manipulation, measurement and observation
- presentation of data and observations
- analysis, conclusions and evaluation.

Centres should refer to the document 'How to manage your sciences practical exams' for advice on making entries and organisation of candidates for practical exams.

Paper 3 consists of two or three questions, totalling 40 marks. The paper:

- requires candidates to carry out an investigation or investigations. They may be asked to:
  - make decisions on techniques
  - collect quantitative or qualitative data
  - present the data or observations as tables, charts, graphs and other appropriate means
  - analyse the data appropriately, including calculations
  - draw conclusions
  - suggest improvements to the procedure or modifications for extending the investigation
- requires candidates to carry out activities using a light microscope. They may be asked to:
  - prepare slides
  - make observations of specimens
  - present their observations appropriately
  - analyse data appropriately, including calculations
  - make deductions and conclusions from the observations

- requires each centre to provide microscopes for half of the candidates at a time (see Apparatus and materials section for microscope specifications), so half the candidates should start on the investigation while the others start with access to the light microscope
- includes questions set in different areas of AS Level Biology, and may include material from unfamiliar contexts.

Candidates will be expected to show evidence of skills in the handling of familiar and unfamiliar biological material. Where unfamiliar materials or techniques are required, full instructions will be given.

No dissection of materials of animal origin will be required in Paper 3. However, the use of dissection, interactive videos or similar will continue to be a useful aid to teaching, e.g. when the heart is being studied.

The apparatus requirements for Paper 3 will vary from paper to paper. A complete list of apparatus and materials required will be issued to centres in the confidential instructions. The confidential instructions should be followed very carefully. If there are any queries regarding the confidential instructions, centres should contact Cambridge International as soon as possible.

Mark allocations for Paper 3

Marks will be allocated on Paper 3 according to the table below. The expectations for each skill are listed in the sections that follow.

Skill	Breakdown of skills	Total marks
Manipulation, measurement and observation	Decisions relating to measurements and observations	15–17
	Collection of data and observations	
Presentation of data and observations	Recording data and observations	11–13
	Display of calculation and reasoning	
	Layout of data and observations	
Analysis, conclusions and evaluation	Interpreting data and observations	11–13
	Drawing conclusions	
	Identifying sources of error and suggesting improvements	

Expectations for each skill (Paper 3)

Manipulation, measurement and observation

Decisions relating to measurements and observations

Within an investigation, candidates should be able to:

- identify the independent variable and dependent variable
- decide a suitable range of values to use for the **independent variable** at which measurements of the **dependent variable** are recorded
- decide the number of different values of the independent variable (a minimum of five) and the intervals between them
- decide how to change the value of the independent variable
- decide how the **dependent variable** should be measured
- decide the number of replicates at each value
- decide on appropriate controls for the experiment or investigation
- decide which variables need to be standardised and how to standardise them. (Variables expected to have a minimal effect, such as variation between test-tubes of the same type, do not need to be standardised.)

When using the light microscope and photomicrographs, candidates should be able to:

- set up a light microscope to view and observe specimens
- follow instructions to find and draw particular tissues in plant and animal specimens and label the drawings appropriately
- follow instructions to find and draw particular cells and structures within the cells
- make a temporary slide of stained cells or tissues
- calculate actual sizes of tissues or cells from measurements of photomicrographs, using magnifications, scale bars or representations of eyepiece graticules and stage micrometers
- estimate the number of cells or cell organelles in a given area using a sampling method, such as grids or fields of view.

Collection of data and observations

Within an investigation, candidates should be able to:

- follow instructions to collect results
- consider the hazards of the procedure, including the use of any solutions and reagents, and assess the risk as low, medium or high
- take readings to obtain accurate data (quantitative results) or observations (qualitative results).

When using the light microscope and photomicrographs, candidates should be able to:

- draw plan diagrams to show the distribution of tissues in a specimen, with no cells drawn and the correct proportions of layers of tissues
- draw the observable features of cells in a specimen showing:
  - the correct shapes
  - the thicknesses of cell walls where applicable (drawn with two lines or drawn with three lines where two cells touch)
  - the relative sizes and proportions
  - observable cell contents only

- measure tissue layers or cells from photomicrographs using a ruler or given scale, including representations of eyepiece graticules
- make accurate observations from specimens including counting numbers of cells or cell organelles
- record similarities and differences between two specimens using only their observable features.

Presentation of data and observations

Recording data and observations

Within an investigation, candidates should be able to:

- record raw results (unprocessed) and calculated results (processed) in an appropriate table with:
  - descriptive headings, including any required units (no units in body of table)
  - heading for the independent variable to the left of (or above, if the table is in rows) the dependent variable
- record quantitative data to the number of decimal places that is appropriate for the measuring instrument used
- record qualitative observations using clear descriptions
- record calculated values (processed results) in an appropriate table.

When using the light microscope and photomicrographs, candidates should be able to:

- record the fine details of the specimen, including drawing the detailed shapes of layers or outlines of specimens in plan diagrams and drawing the shape and position of observable cell organelles in cells.

Display of calculation and reasoning

Within an investigation and when using the light microscope and photomicrographs, candidates should be able to:

- display calculations clearly, showing all the steps and reasoning
- use the correct number of significant figures for calculated quantities. This should be the same as, or one more than, the smallest number of significant figures in the data used in the calculation.

Layout of data and observations

Within an investigation, candidates should be able to:

- display data as a graph (continuous data), bar chart (discontinuous or categoric) or histogram (frequency data)
- draw a graph, bar chart or histogram clearly and accurately with:
  - the independent variable on the *x*-axis and the dependent variable on the *y*-axis
  - axes labelled to match the relevant table headings, including units where appropriate
  - a scale where both axes should use most or all of the grid available and allow the graph to be read easily to within half a square
  - all graph points plotted accurately using a sharp pencil, as a small cross or a small dot in a circle, with the intersection of the cross or centre of the dot exactly on the required point
  - the plotted points of a graph connected with a clear, sharp and unbroken line, either as a line of best fit, a smooth curve or with ruled straight lines joining the points
  - no extrapolation of graph lines unless this can be assumed from the data
  - all bars on a bar chart or histogram plotted accurately, with clear, unbroken lines that are drawn with a sharp pencil and ruler.

When using the light microscope and photomicrographs, candidates should be able to:

- make drawings, using a sharp pencil to give finely drawn lines that are clear and unbroken
- make drawings that use most of the available space and show all the features observed in the specimen, with no shading
- organise comparative observations, showing differences and similarities between specimens.

Analysis, conclusions and evaluation

Interpreting data and observations

Within an investigation, candidates should be able to:

- calculate an answer with the correct number of significant figures using quantitative results or data provided
- use a graph to find unknown values
- estimate the concentrations of unknown solutions from qualitative results
- identify the contents of unknown solutions using biological molecule tests
- identify anomalous results and suggest how to deal with anomalies
- describe patterns and trends using the data provided in tables and graphs
- evaluate the confidence with which conclusions might be made.

When using the light microscope and photomicrographs, candidates should be able to:

- calculate an answer with the correct number of significant figures using quantitative results or data provided
- compare observable features of specimens of biological material including similarities and differences between specimens on a microscope slide and specimens in photomicrographs.

Drawing conclusions

From results, observations or information provided, candidates should be able to:

- summarise the main conclusions
- state and explain whether a hypothesis is supported
- make predictions from the patterns and trends in data
- suggest explanations for observations, results, patterns, trends and conclusions.

Identifying sources of error and suggesting improvements

Within an investigation and when using the light microscope and photomicrographs, candidates should be able to:

- identify systematic or random errors in an investigation, understanding that systematic errors may not affect the trend in results whereas a random error may affect the trend
- identify the main sources of error in a particular investigation
- suggest improvements to a procedure that will increase the accuracy of the observations or measurements, including:
  - using a more effective method to standardise relevant variables
  - using a more accurate method of measuring the dependent variable
  - using smaller intervals for the values of the independent variable
  - collecting replicate measurements so that a mean can be calculated
- suggest how to extend the investigation to answer a new question, for example by investigating a different independent variable or applying the method to a new context
- describe clearly, in words or diagrams, improvements to the procedure or modifications to extend the investigation.

Administration of Paper 3

Detailed regulations on the administration of Cambridge International practical examinations are contained in the *Cambridge Handbook*.

Details of specific requirements for apparatus and materials for a particular examination are given in the confidential instructions, which are sent to centres several weeks before the examination. Any materials to be supplied by Cambridge International (such as prepared microscope slides or enzymes) are clearly identified in the confidential instructions and are sent to centres several weeks before the examination. Centres should contact Cambridge International if they have not received the confidential instructions or the materials to be supplied by Cambridge International.

It is the responsibility of centres to provide the apparatus and chemicals for practical examinations. Cambridge International is not able to supply apparatus and chemicals directly, nor provide advice on local suppliers.

Apparatus and materials

This section lists the apparatus and materials that are expected to be available within centres for use during the practical exams. Candidates should be accustomed to using these. The lists are not intended to be exhaustive and confidential instructions may state other apparatus and materials that will be required within specific assessments.

This section also includes some guidance notes on safety.

List of apparatus

- microscopes, with lamp or inbuilt illumination, fitted with:
  - an eyepiece lens, ×10 magnification
  - a low-power objective lens, ×10 magnification
  - a high-power objective lens, ×40 magnification

  any lenses which are not ×10 or ×40 should be removed or replaced
- microscope slides and glass coverslips
- test-tubes, small, capacity 20–30 cm^3 including some that are heat resistant
- test-tubes, large (boiling tubes), capacity 40–50 cm^3 including some that are heat resistant
- test-tube holders
- test-tube racks
- bungs to fit small test-tubes and large test-tubes
- bungs with delivery tube to fit small test-tubes and large test-tubes
- specimen tubes with lids
- Bunsen burners
- tripods and gauzes
- heat-proof mats (bench mats)
- measuring cylinders
- syringes (various sizes, e.g. 1 cm^3, 2 cm^3 or 3 cm^3, 5 cm^3, 10 cm^3)
- clear plastic tubing to fit syringe nozzles
- small teat pipettes or droppers (plastic or glass)
- beakers (various sizes, e.g. 100 cm^3, 250 cm^3 , 400 cm^3)
- thermometers, –10 °C to +110 °C

- filter funnels and filter paper
- Petri dishes, plastic or glass, 9 cm diameter
- white tiles or other suitable surfaces on which to cut
- spotting tiles (dimple tiles) with at least 12 wells
- clamp (retort) stands and bosses
- dialysis (Visking) tubing, 14 mm width with a pore diameter of approximately 2.5 nm
- capillary tubing
- soda-glass tubing
- paper towels
- glass (stirring) rods
- spatulas
- black paper or black card
- white paper or white card
- water-resistant marker pens (for labelling glassware)
- blunt forceps
- scissors
- mounted needles
- cutting implement, such as single-edged razor blade / knife / scalpel
- rulers in mm (ideally clear plastic)
- mortars and pestles
- suitable eye protection
- cork borers
- stop-clock or timer showing seconds

Materials

In the list of materials the following hazard codes are used, in accordance with information provided by CLEAPSS[1]:

C	corrosive	**MH**	moderate hazard
HH	health hazard	**T**	acutely toxic
F	flammable	**O**	oxidising
N	hazardous to the aquatic environment		

[1] An advisory service providing support in practical science and technology for schools and colleges (**www.cleapss.org.uk**)

List of materials

- **[N]** – iodine in potassium iodide solution (suitable for starch test)
- **[MH] [N]** – Benedict's solution (suitable for qualitative reducing sugar test)
- **[C] [MH]** – biuret reagent or potassium hydroxide and copper sulfate solution (suitable for biuret test for proteins)
- **[F] [MH] [HH]** – ethanol or IDA (suitable for emulsion test for lipids)
- sucrose, Analar (AR)
- glucose
- starch
- albumen
- **[C] [MH]** potassium hydroxide
- **[C]** sodium hydroxide
- sodium chloride
- dilute hydrochloric acid
- hydrogencarbonate indicator
- sodium hydrogencarbonate
- **[MH]** limewater
- **[MH]** hydrogen peroxide
- distilled or deionised water
- universal indicator paper with chart
- universal indicator solution with chart
- red and blue litmus paper
- **[F] [MH] [HH]** thymolphthalein indicator
- **[F] [MH] [HH]** bromothymol blue
- **[HH]** methylene blue
- petroleum jelly
- DCPIP (2,6-dichlorophenol-indophenol)
- ascorbic acid (vitamin C)
- **[HH]** enzymes: amylase, bacterial protease
- materials for preparing immobilised enzymes: calcium chloride, sodium alginate
- plant sources of catalase, e.g. sweet potatoes, mung beans, potatoes
- yeast, dried
- **[MH] [N]** copper sulfate, hydrated
- **[O] [MH] [HH] [N]** potassium manganate(VII), also known as potassium permanganate
- technical agar

Safety in the laboratory

Responsibility for safety matters rests with centres.

Supervisors must follow national and local regulations relating to safety and first aid.

Hazard Data Sheets relating to substances should be available from your chemical supplier.

Paper 5

Paper 5 is a timetabled, written paper focusing on the following higher-order practical skills of:

- planning
- analysis
- conclusions
- evaluation.

This exam will not require laboratory facilities.

To prepare candidates for this exam, it should be emphasised that candidates will need extensive experience of laboratory work of A Level standard. This requires many hours of laboratory-based work, with careful supervision from teachers to ensure that experiments are planned and carried out safely.

Paper 5 may include questions assessing both the AS and A Level syllabus and may include unfamiliar contexts. Where questions include theory or equipment which would be unfamiliar to candidates, information will be provided in the question.

Paper 5 consists of two or more questions totalling 30 marks.

Candidates are required to:

- use extended structured writing
- use appropriate diagrams and tables to illustrate answers
- design an experimental method for a given problem, for which they may be asked to use given information or a specific piece of apparatus
- express a prediction linking independent and dependent variables, either as a written hypothesis or as a graph showing the expected result
- analyse and evaluate given experimental data, presented as tables, graphs or written statements, and draw appropriate conclusions
- identify appropriate mathematical or statistical methods to process experimental data.

Mark allocations for Paper 5

Marks will be allocated on Paper 5 according to the table below. The expectations for each skill are listed in the sections that follow.

Skill	Breakdown of skills	Total marks
Planning	Defining the problem	14–16
	Methods	
Analysis, conclusions and evaluation	Dealing with data	14–16
	Conclusions	
	Evaluation	

Expectations for each skill (Paper 5)

Planning

Candidates will develop a procedure to test a hypothesis or prediction based on an experimental context and appropriate background information.

Defining the problem

Using the context provided, candidates should be able to:

- state a relevant prediction, either in words or in the form of a sketch graph showing the expected result, and link this to an underlying hypothesis
- identify the independent and dependent variables
- identify which key variables must be standardised in order to test a hypothesis. (Variables expected to have a minimal effect, such as variation between test-tubes of the same type, do not need to be standardised.)

Methods

Using the context provided, candidates should be able to:

- describe how to vary the independent variable
- describe how to measure the values of the independent and dependent variables accurately and to an appropriate precision
- describe how to standardise each of the other key variables
- describe, where appropriate, suitable volumes and concentrations of reagents. Concentrations may be specified in % (w/v), or mol dm^{-3}
- describe how different concentrations would be prepared by serial dilution or proportional dilution
- describe appropriate control experiments
- describe, in a logical sequence, the steps involved in the procedure, including how to use the apparatus to collect results
- describe how the quality of results can be assessed by considering:
  - the occurrence of anomalous results
  - the spread of results including the use of standard deviation, standard error and/or 95% confidence intervals (95% CI).

- describe how to assess the validity of the results by considering both the accuracy of the measurements and the repeatability of the results
- prepare a simple risk assessment of their plans, taking into account the severity of any hazards and the probability that a problem could occur
- describe the precautions that would need to be taken to minimise risks where possible.

Analysis, conclusions and evaluation

Analysis, conclusions and evaluation tests the ability of candidates to process given data in a variety of ways.

Dealing with data

Knowledge of the Mathematical requirements in section 6 of the syllabus is expected.

From provided data, candidates should be able to:

- use tables and graphs to show the key points in quantitative data
- sketch or draw suitable graphs, displaying the independent variable on the *x*-axis and the dependent variable on the *y*-axis including, where required, confidence limit error bars
- decide which calculations are necessary in order to draw conclusions
- carry out appropriate calculations to simplify or explain data, including means, percentages and rates of change
- carry out calculations in order to compare data, including percentage gain or loss
- use values of standard deviation or standard error, or graphs with standard error bars, to determine whether differences in mean values are likely to be statistically significant
- choose and carry out statistical tests (limited to those described in the Mathematical requirements section of the syllabus) appropriate to the type of data collected and justify use of these tests
- state a null hypothesis for a statistical test
- recognise the different types of variable and the different types of data presented, as shown in the table below.

Type of variable	Type of data
Qualitative	
categoric	nominal, i.e. values or observations belonging to it can be sorted according to category, e.g. colour of flowers
ordered	ordinal, where values can be placed in an order or rank and the interval between them may not be equal, e.g. the order in which test-tubes containing starch and iodine become colourless after adding amylase
Quantitative	continuous, which can have any value within a specific range, e.g. body mass, leaf length

Conclusions

Candidates should be able to:

- summarise the main conclusions from the results
- identify key points of the raw data and processed data, including graphs and statistical test results
- discuss the extent to which a given hypothesis is supported by experimental data and the strengths and weaknesses of the evidence
- give detailed scientific explanations of the conclusions
- make further predictions and hypotheses based on the conclusions.

Evaluation

Candidates should be able to:

- identify anomalous values in a table or graph of data and suggest how to deal with anomalies
- suggest possible explanations for anomalous readings
- assess whether the results have been replicated sufficiently
- assess whether the range of values of the independent variable and the intervals between the values were appropriate
- assess whether the method of measuring is appropriate for the dependent variable
- assess the extent to which selected variables have been effectively controlled
- make informed judgements about:
  - the validity of the investigation
  - the extent to which the data can be used to test the hypothesis
  - how much confidence can be put in the conclusions
- suggest how an investigation could be improved to increase confidence in the results.

6 Additional information

Mathematical requirements

Candidates are expected to use the following mathematical skills and knowledge in the assessment. Teaching the mathematical requirements should be included in the AS & A Level Biology course.

At AS Level and A Level

Candidates should be able to:

- understand and use the prefixes: giga (G), mega (M), kilo (k), milli (m), micro (μ) and nano (n)
- select and use the most appropriate units for recording data and the results of calculations
- recognise and use numbers in decimal and standard form
- understand and use the symbols: < (less than), > (greater than), ⩽ (less than or equal to), ⩾ (greater than or equal to), / (solidus followed by unit in table headings and labels for graph axes), ∝ (is directly proportional to) and Σ (sum of)
- make estimations of the results of calculations
- use a calculator for addition, subtraction, multiplication and division, and to calculate squares (x^2), square roots ($\sqrt{x}$), reciprocals ($\frac{1}{x}$), logs (lg) and means ($\bar{x}$)
- take account of significant figures in calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified. (The correct number of significant figures for calculated quantities is the same as, or one more than, the smallest number of significant figures in the data used in the calculation.)
- record data from experiments to an appropriate and consistent precision
- calculate magnifications and actual sizes
- calculate areas of triangles, rectangles and circles
- calculate perimeters of rectangles and circumferences of circles
- calculate surface areas and volumes of cuboids and cylinders
- calculate the mean, median, mode and range of a set of values
- recognise and use ratios
- calculate percentages and percentage changes
- express errors in experimental work as percentage errors
- translate information between graphical, numerical, and algebraic forms
- construct and interpret diagrammatic representations of data, including line graphs, pie charts, bar charts and histograms
- understand when data should be presented in the form of a bar chart, histogram or line graph
- plot data on graph paper with the variables correctly orientated on the axes and with each axis scaled appropriately
- recognise when it is appropriate to join the points on a graph with straight ruled lines and when it is appropriate to use a line (straight or curved) of best fit
- calculate the rate of change from the gradient of a straight line on a graph
- calculate the rate of change from the gradient of a tangent to a curved line on a graph.

At A Level only

Candidates should be able to:

- relate genetic ratios to probabilities
- understand the principles of sampling as applied to biological situations and data
- understand the importance of chance and probability when interpreting data
- use the Hardy–Weinberg equations to calculate allele and genotype frequencies in populations (formulae will be provided – see Mathematical formulae)
- use the Lincoln index to calculate an estimate of population size using mark-release-recapture data (formula will be provided – see Mathematical formulae)
- calculate Simpson's index of diversity (*D*) (formula will be provided – see Mathematical formulae)
- understand the difference between a normal distribution and a distribution that is non-normal
- understand the use of descriptive statistics to simplify data, including the mean, median, mode, range, standard deviation, standard error and 95% confidence intervals (mean, median, mode and range are also expected at AS Level)
- calculate sample standard deviation, standard error and 95% confidence intervals (formulae will be provided – see Mathematical formulae)
- use standard deviations, standard errors or 95% confidence intervals to plot error bars on graphs
- understand the difference between correlation and causation and that a correlation does not necessarily imply a causative relationship
- calculate the results of chi-squared tests and *t*-tests (formulae will be provided – see Mathematical formulae)
- calculate the number of degrees of freedom for chi-squared tests and *t*-tests (formulae will **not** be provided – see Mathematical formulae)
- use the results of chi-squared tests and *t*-tests, together with the relevant probability tables of critical values, to assess the significance of differences (tables of critical values will be provided)
- use Pearson's linear correlation and Spearman's rank correlation to test for correlation (formulae will be provided – see Mathematical formulae)
- understand when it is appropriate to use the different statistical tests (chi-squared test, *t*-test, Pearson's linear correlation and Spearman's rank correlation) and the conditions in which each is valid.

Mathematical formulae (A Level only)

Candidates are **not** expected to remember the formulae and symbols for the mathematical formulae in the table below. When needed, candidates will be provided with this information.

Hardy–Weinberg equations	
equation 1: $p + q = 1$ **equation 2:** $p^2 + 2pq + q^2 = 1$	Key to symbols: p = frequency of the dominant allele, e.g. **A** q = frequency of the recessive allele, e.g. **a** p^2 = frequency of homozygous dominant genotype, e.g. **AA** $2pq$ = frequency of heterozygous genotype, e.g. **Aa** q^2 = frequency of homozygous recessive genotype, e.g. **aa**
Lincoln index	
$N = \frac{n_1 \times n_2}{m_2}$	Key to symbols: N = estimate of population size n_1 = number of individuals captured in first sample n_2 = number of individuals (both marked and unmarked) captured in second sample m_2 = number of marked individuals recaptured in second sample
Simpson's index of diversity (*D*)	
$D = 1 - \left(\Sigma\left(\frac{n}{N}\right)^2\right)$	Key to symbols: n = number of individuals of each type present in the sample (types may be species and/or higher taxa such as genera, families, etc.) N = the total number of all individuals of all types present in the sample
chi-squared (χ^2) test	
$\chi^2 = \Sigma\frac{(O-E)^2}{E}$	Key to symbols: O = observed value E = expected value
sample standard deviation (s)	
$s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$	Key to symbols: x = observation $\bar{x}$ = mean n = sample size (number of observations)
standard error (SE)	
$\text{SE} = \frac{s}{\sqrt{n}}$	Key to symbols: s = sample standard deviation n = sample size (number of observations)

95% confidence intervals (95% CI)

You can assume this approximation:

95% CI = $\bar{x} \pm (2 \times \text{SE})$

Key to symbols:

$\bar{x}$ = mean

SE = standard error

***t*-test**

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

Key to symbols:

$\bar{x}$ = mean

s = sample standard deviation

n = sample size (number of observations)

Pearson's linear correlation (*r*)

$$r = \frac{\sum xy - n\bar{x}\bar{y}}{(n-1)s_x s_y}$$

Key to symbols:

x, y = observations

$\bar{x}, \bar{y}$ = means

n = sample size (number of observations)

s = sample standard deviation

Spearman's rank correlation (r_s)

$$r_s = 1 - \left(\frac{6 \times \sum D^2}{n^3 - n}\right)$$

Key to symbols:

D = difference in rank between each pair of measurements

n = number of pairs of items in the sample

Number of degrees of freedom for the chi-squared test and the *t*-test

In both the *t*-test and the chi-squared test, candidates are expected to know how to calculate the number of degrees of freedom, without being provided with the formulae.

number of degrees of freedom (v) for the chi-squared test

$v = c - 1$

Key to symbols:

c = number of classes

number of degrees of freedom (v) for the *t*-test

$v = n_1 + n_2 - 2$

Key to symbols:

n = sample size (number of observations)

Notes on the use of statistics in Biology (A Level only)

Paper 4 and Paper 5 may include questions involving the use of descriptive statistics and the statistical tests stated in the syllabus. Candidates will **not** be expected to carry out all the steps in calculations of sample standard deviations, *t*-tests, Pearson's linear correlation and Spearman's rank correlation during an examination, but they may be given partly completed calculations to finish.

Candidates are allowed to use electronic calculators in the examination, as long as they are permitted by the Cambridge International general regulations.

The **chi-squared** test is used to test whether the difference between observed and expected frequencies of nominal data is significant. The chi-squared test is commonly used in the context of evaluating the results of breeding experiments and some forms of ecological sampling. Chi-squared tests will only be expected on one row or one column of data.

The ***t*-test** is used to test for the significance of differences between two samples, each with continuous data, including samples with fewer than 30 values. This test can be used if:

- continuous data have been collected
- the data are from populations that are normally distributed
- standard deviations are approximately the same.

Candidates should be able to use **Pearson's linear correlation** to test for a correlation between two sets of normally distributed data. The test can be used if:

- continuous data have been collected
- a scatter diagram indicates the possibility of a linear relationship
- the data are from a population that is normally distributed
- there are at least five paired observations, although ideally the number of paired observations should be ten or more.

Spearman's rank correlation is used to test for a correlation between two sets of data that are not distributed normally. The test can be used if:

- data points within samples are independent of each other
- ordinal data have been collected or the data that have been collected can be converted to an ordinal scale using ranking
- a scatter diagram indicates the possibility of an increasing or a decreasing relationship
- there are more than five paired observations, although ideally the number of paired observations should be between 10 and 30
- all individuals were selected at random from a population and each individual had an equal chance of being selected.

For both Pearson's linear correlation and Spearman's rank correlation, candidates should know that correlations exist between –1 (perfect negative correlation), 0 (no correlation) and +1 (perfect positive correlation).

These statistical methods are dealt with fully in many textbooks and websites on statistics for biology.

7 What else you need to know

This section is an overview of other information you need to know about this syllabus. It will help to share the administrative information with your exams officer so they know when you will need their support. Find more information about our administrative processes at **www.cambridgeinternational.org/eoguide**

Before you start

Previous study

We recommend that learners starting this course should have completed a course in Biology or Co-ordinated Science equivalent to Cambridge IGCSE™ or Cambridge O Level.

Guided learning hours

We design Cambridge International AS & A Level syllabuses to require about 180 guided learning hours for each Cambridge International AS Level and about 360 guided learning hours for a Cambridge International A Level. The number of hours a learner needs to achieve the qualification may vary according to each school and the learners' previous experience of the subject.

Availability and timetables

All Cambridge schools are allocated to an administrative zone. Each zone has a specific timetable.

You can view the timetable for your administrative zone at **www.cambridgeinternational.org/timetables**

You can enter candidates in the June and November exam series. If your school is in India, you can also enter your candidates in the March exam series.

Check you are using the syllabus for the year the candidate is taking the exam.

Private candidates can enter for this syllabus. For more information, please refer to the *Cambridge Guide to Making Entries*.

Combining with other syllabuses

Candidates can take this syllabus alongside other Cambridge International syllabuses in a single exam series. The only exceptions are:

- syllabuses with the same title at the same level.

Group awards: Cambridge AICE

Cambridge AICE (Advanced International Certificate of Education) is a group award for Cambridge International AS & A Level. It allows schools to offer a broad and balanced curriculum by recognising the achievements of learners who pass exams in a range of different subjects.

Learn more about Cambridge AICE at **www.cambridgeinternational.org/aice**

Making entries

Exams officers are responsible for submitting entries to Cambridge International. We encourage them to work closely with you to make sure they enter the right number of candidates for the right combination of syllabus components. Entry option codes and instructions for submitting entries are in the *Cambridge Guide to Making Entries*. Your exams officer has a copy of this guide.

Exam administration

To keep our exams secure, we produce question papers for different areas of the world, known as administrative zones. We allocate all Cambridge schools to one administrative zone determined by their location. Each zone has a specific timetable. Some of our syllabuses offer candidates different assessment options. An entry option code is used to identify the components the candidate will take relevant to the administrative zone and the available assessment options.

Support for exams officers

We know how important exams officers are to the successful running of exams. We provide them with the support they need to make your entries on time. Your exams officer will find this support, and guidance for all other phases of the Cambridge Exams Cycle, at **www.cambridgeinternational.org/eoguide**

Retakes and carrying forward marks

Candidates can retake Cambridge International AS Level and Cambridge International A Level as many times as they want to. Information on retake entries is at **www.cambridgeinternational.org/retakes**

Candidates can carry forward the result of their Cambridge International AS Level assessment from one series to complete the Cambridge International A Level in a following series, subject to the rules and time limits described in the *Cambridge Handbook*.

Language

This syllabus and the related assessment materials are available in English only.

Accessibility and equality

Syllabus and assessment design

Cambridge International works to avoid direct or indirect discrimination. We develop and design syllabuses and assessment materials to maximise inclusivity for candidates of all national, cultural or social backgrounds and candidates with protected characteristics; these protected characteristics include special educational needs and disability, religion and belief, and characteristics related to gender and identity. In addition, the language and layout used are designed to make our materials as accessible as possible. This gives all candidates the fairest possible opportunity to demonstrate their knowledge, skills and understanding and helps to minimise the requirement to make reasonable adjustments during the assessment process.

Access arrangements

Access arrangements (including modified papers) are the principal way in which Cambridge International complies with our duty, as guided by the UK Equality Act (2010), to make ‘reasonable adjustments’ for candidates with special educational needs (SEN), disability, illness or injury. Where a candidate would otherwise be at a substantial disadvantage in comparison to a candidate with no SEN, disability, illness or injury, we may be able to agree pre-examination access arrangements. These arrangements help a candidate by minimising accessibility barriers and maximising their opportunity to demonstrate their knowledge, skills and understanding in an assessment.

Important:

- Requested access arrangements should be based on evidence of the candidate's barrier to assessment and should also reflect their normal way of working at school; this is in line with the *Cambridge Handbook* **www.cambridgeinternational.org/eoguide**
- For Cambridge International to approve an access arrangement, we will need to agree that it constitutes a reasonable adjustment, involves reasonable cost and timeframe and does not affect the security and integrity of the assessment.
- Availability of access arrangements should be checked by centres at the start of the course. Details of our standard access arrangements and modified question papers are available in the *Cambridge Handbook* **www.cambridgeinternational.org/eoguide**
- Please contact us at the start of the course to find out if we are able to approve an arrangement that is not included in the list of standard access arrangements.
- Candidates who cannot access parts of the assessment may be able to receive an award based on the parts they have completed.

After the exam

Grading and reporting

Grades A*, A, B, C, D or E indicate the standard a candidate achieved at Cambridge International A Level. A* is the highest and E is the lowest grade.

Grades a, b, c, d or e indicate the standard a candidate achieved at Cambridge International AS Level. 'a' is the highest and 'e' is the lowest grade.

'Ungraded' means that the candidate's performance did not meet the standard required for the lowest grade (E or e). 'Ungraded' is reported on the statement of results but not on the certificate. In specific circumstances your candidates may see one of the following letters on their statement of results:

- Q (PENDING)
- X (NO RESULT).

These letters do not appear on the certificate.

If a candidate takes a Cambridge International A Level and fails to achieve grade E or higher, a Cambridge International AS Level grade will be awarded if both of the following apply:

- the components taken for the Cambridge International A Level by the candidate in that series included all the components making up a Cambridge International AS Level
- the candidate's performance on the AS Level components was sufficient to merit the award of a Cambridge International AS Level grade.

On the statement of results and certificates, Cambridge International AS & A Levels are shown as General Certificates of Education, GCE Advanced Subsidiary Level (GCE AS Level) and GCE Advanced Level (GCE A Level).

School feedback: 'Cambridge International A Levels are the 'gold standard' qualification. They are based on rigorous, academic syllabuses that are accessible to students from a wide range of abilities yet have the capacity to stretch our most able.'

Feedback from: Director of Studies, Auckland Grammar School, New Zealand

How students, teachers and higher education can use the grades

Cambridge International A Level

Assessment at Cambridge International A Level has two purposes:

1 to measure learning and achievement

The assessment confirms achievement and performance in relation to the knowledge, understanding and skills specified in the syllabus, to the levels described in the grade descriptions.

2 to show likely future success

The outcomes help predict which students are well prepared for a particular course or career and/or which students are more likely to be successful.

The outcomes help students choose the most suitable course or career.

Cambridge International AS Level

Assessment at Cambridge International AS Level has two purposes:

1 to measure learning and achievement

The assessment confirms achievement and performance in relation to the knowledge, understanding and skills specified in the syllabus.

2 to show likely future success

The outcomes help predict which students are well prepared for a particular course or career and/or which students are more likely to be successful.

The outcomes help students choose the most suitable course or career.

The outcomes help decide whether students part way through a Cambridge International A Level course are making enough progress to continue.

The outcomes guide teaching and learning in the next stages of the Cambridge International A Level course.

Grade descriptions

Grade descriptions are provided to give an indication of the standards of achievement candidates awarded particular grades are likely to show. Weakness in one aspect of the examination may be balanced by a better performance in some other aspect.

Grade descriptions for Cambridge International A Level Biology will be published after the first assessment of the A Level in 2022.

Changes to this syllabus for 2025, 2026 and 2027

The syllabus has been updated. This is version 2, published October 2026.

You must read the whole syllabus before planning your teaching programme. We review our syllabuses regularly to make sure they continue to meet the needs of our schools. In updating this syllabus, we have made it easier for teachers and students to understand, keeping the familiar features that teachers and schools value.

Changes to version 2 of the syllabus, published October 2026.

Other changes	• A weblink on page 68 has been updated.

Changes to version 1 of the syllabus, published September 2022.

Changes to syllabus content	• An addition has been made to the List of materials for paper 3 • An addition has been made to the command words

Significant changes to the syllabus are indicated by black vertical lines either side of the text.

Any textbooks endorsed to support the syllabus for examination from 2022 are still suitable for use with this syllabus.

School feedback: ‘While studying Cambridge IGCSE and Cambridge International A Levels, students broaden their horizons through a global perspective and develop a lasting passion for learning.’

Feedback from: Zhai Xiaoning, Deputy Principal, The High School Affiliated to Renmin University of China

We are committed to making our documents accessible in accordance with the WCAG 2.1 Standard. We are always looking to improve the accessibility of our documents. If you find any problems or you think we are not meeting accessibility requirements, contact us at **info@cambridgeinternational.org** with the subject heading: Digital accessibility. If you need this document in a different format, contact us and supply your name, email address and requirements and we will respond within 15 working days.

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