CAMBRIDGE
International Examinations

Cambridge International AS & A Level

SYLLABUS

Cambridge International AS and A Level Biology

9700

For examination in June and November 2015

Cambridge Advanced

Changes to syllabus for 2015

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

Contents

1. Introduction

1.1 Why choose Cambridge?

Recognition

Cambridge International Examinations is the world's largest provider of international education programmes and qualifications for learners aged 5 to 19. We are part of Cambridge Assessment, a department of the University of Cambridge, trusted for excellence in education. Our qualifications are recognised by the world's universities and employers.

Cambridge International AS and A Levels are recognised around the world by schools, universities and employers. The qualifications are accepted as proof of academic ability for entry to universities worldwide, though some courses do require specific subjects.

Cambridge International A Levels typically take two years to complete and offer a flexible course of study that gives learners the freedom to select subjects that are right for them.

Cambridge International AS Levels often represent the first half of an A Level course but may also be taken as a freestanding qualification. The content and difficulty of a Cambridge International AS Level examination is equivalent to the first half of a corresponding Cambridge International A Level. Cambridge AS Levels are accepted in all UK universities and carry half the weighting of an A Level. University course credit and advanced standing is often available for Cambridge International AS and A Levels in countries such as the USA and Canada.

Learn more at **www.cie.org.uk/recognition**

Excellence in education

Our mission is to deliver world-class international education through the provision of high-quality curricula, assessment and services.

More than 9000 schools are part of our Cambridge learning community. We support teachers in over 160 countries who offer their learners an international education based on our curricula and leading to our qualifications. Every year, thousands of learners use Cambridge qualifications to gain places at universities around the world.

Our syllabuses are reviewed and updated regularly so that they reflect the latest thinking of international experts and practitioners and take account of the different national contexts in which they are taught.

Cambridge programmes and qualifications are designed to support learners in becoming:

- **confident** in working with information and ideas – their own and those of others
- **responsible** for themselves, responsive to and respectful of others
- **reflective** as learners, developing their ability to learn
- **innovative** and equipped for new and future challenges
- **engaged** intellectually and socially, ready to make a difference.

Support for teachers

A wide range of support materials and resources is available for teachers and learners in Cambridge schools. Resources suit a variety of teaching methods in different international contexts. Through subject discussion forums and training, teachers can access the expert advice they need for teaching our qualifications. More details can be found in Section 2 of this syllabus and at **www.cie.org.uk/teachers**

Support for exams officers

Exams officers can trust in reliable, efficient administration of exam entries and excellent personal support from our customer services. Learn more at **www.cie.org.uk/examsofficers**

Not-for-profit, part of the University of Cambridge

We are a not-for-profit organisation where the needs of the teachers and learners are at the core of what we do. We continually invest in educational research and respond to feedback from our customers in order to improve our qualifications, products and services.

Our systems for managing the provision of international qualifications and education programmes for learners aged 5 to 19 are certified as meeting the internationally recognised standard for quality management, ISO 9001:2008. Learn more at **www.cie.org.uk/ISO9001**

1.2 Why choose Cambridge International AS and A Level?

Cambridge International AS and A Levels are international in outlook, but retain a local relevance. The syllabuses provide opportunities for contextualised learning and the content has been created to suit a wide variety of schools, avoid cultural bias and develop essential lifelong skills, including creative thinking and problem-solving.

Our aim is to balance knowledge, understanding and skills in our programmes and qualifications to enable candidates to become effective learners and to provide a solid foundation for their continuing educational journey. Cambridge International AS and A Levels give learners building blocks for an individualised curriculum that develops their knowledge, understanding and skills.

Schools can offer almost any combination of 60 subjects and learners can specialise or study a range of subjects, ensuring a breadth of knowledge. Giving learners the power to choose helps motivate them throughout their studies.

Through our professional development courses and our support materials for Cambridge International AS and A Levels, we provide the tools to enable teachers to prepare learners to the best of their ability and work with us in the pursuit of excellence in education.

Cambridge International AS and A Levels have a proven reputation for preparing learners well for university, employment and life. They help develop the in-depth subject knowledge and understanding which are so important to universities and employers.

Learners studying Cambridge International AS and A Levels have the opportunities to:

- acquire an in-depth subject knowledge
- develop independent thinking skills
- apply knowledge and understanding to new as well as familiar situations
- handle and evaluate different types of information sources
- think logically and present ordered and coherent arguments
- make judgements, recommendations and decisions
- present reasoned explanations, understand implications and communicate them clearly and logically
- work and communicate in English.

Guided learning hours

Cambridge International A Level syllabuses are designed on the assumption that candidates have about 360 guided learning hours per subject over the duration of the course. Cambridge International AS Level syllabuses are designed on the assumption that candidates have about 180 guided learning hours per subject over the duration of the course. This is for guidance only and the number of hours required to gain the qualification may vary according to local curricular practice and the learners' prior experience of the subject.

1.3 Why choose Cambridge International AS and A Level Biology?

Cambridge International AS and A Level Biology is accepted by universities and employers as proof of knowledge and understanding of biology. Successful candidates gain lifelong skills, including:

- confidence in a technological world, with an informed interest in scientific matters
- an understanding of the usefulness (and limitations) of scientific method, and its application in other subjects and in everyday life
- an understanding of how scientific theories and methods have developed, and continue to develop, as a result of groups and individuals working together
- an understanding that the study and practice of biology are affected and limited by social, economic, technological, ethical and cultural factors
- an awareness that the application of biological science in everyday life may be both helpful and harmful to the individual, the community and the environment
- knowledge that biological science overcomes national boundaries
- the ability to communicate effectively using universal scientific conventions
- an awareness of the importance of IT
- a concern for accuracy and precision
- an understanding of the importance of safe practice
- improved awareness of the importance of objectivity, integrity, enquiry, initiative and inventiveness
- an interest in, and care for, the local and global environment and an understanding of the need for conservation
- an excellent foundation for studies beyond Cambridge International A Level in biological sciences, in further or higher education, and for professional courses.

Prior learning

We recommend that candidates who are beginning this course should have previously completed a Cambridge O Level or Cambridge IGCSE course, or the equivalent, in Biology or in Coordinated Science.

Progression

Cambridge International A Level Biology provides a suitable foundation for the study of Biology or related courses in higher education. Equally it is suitable for candidates intending to pursue careers or further study in Biological Sciences, or as part of a course of general education.

Cambridge International AS Level Biology constitutes the first half of the Cambridge International A Level course in Biology and therefore provides a suitable foundation for the study of Biology at Cambridge International A Level and thereafter for related courses in higher education. Depending on local university entrance requirements, it may permit or assist progression directly to university courses in Biology or some other subjects. It is also suitable for candidates intending to pursue careers or further study in Biology, or as part of a course of general education.

1.4 Cambridge AICE (Advanced International Certificate of Education) Diploma

Cambridge AICE Diploma is the group award of the Cambridge International AS and A Level. It gives schools the opportunity to benefit from offering a broad and balances curriculum by recognising the achievements of learners who pass examinations in three different curriculum groups:

- Mathematics and Science (Group 1)
- Languages (Group 2)
- Arts and Humanities (Group 3)

A Cambridge International A Level counts as a double-credit qualification and a Cambridge International AS Level counts as a single-credit qualification within the Cambridge AICE Diploma award framework.

To be considered for an AICE Diploma, a candidate must earn the equivalent of six credits by passing a combination of examinations at either double credit or single credit, with at least one course coming from each of the three curriculum groups.

Biology (9700) falls into Group 1, Mathematics and Science.

Credits gained from Cambridge AS Level Global Perspectives (8987) or Cambridge Pre-U Global Perspectives and Independent Research (9766) can be counted towards the Cambridge AICE Diploma, but candidates must also gain at least one credit from each of the three curriculum groups to be eligible for the award.

Learn more about the Cambridge AICE Diploma at **www.cie.org.uk/qualifications/academic/uppersec/aice**

The Cambridge AICE Diploma is awarded from examinations administered in the June and November series each year.

Detailed timetables are available from **www.cie.org.uk/examsofficers**

1.5 How can I find out more?

If you are already a Cambridge school

You can make entries for this qualification through your usual channels. If you have any questions, please contact us at **info@cie.org.uk**

If you are not yet a Cambridge school

Learn about the benefits of becoming a Cambridge school at **www.cie.org.uk/startcambridge**. Email us at **info@cie.org.uk** to find out how your organisation can register to become a Cambridge school.

2. Teacher support

2.1 Support materials

Cambridge syllabuses, past question papers and examiner reports to cover the last examination series are on the *Syllabus and Support Materials* DVD, which we send to all Cambridge schools.

You can also go to our public website at **www.cie.org.uk/alevel** to download current and future syllabuses together with specimen papers or past question papers and examiner reports from one series.

For teachers at registered Cambridge schools a range of additional support materials for specific syllabuses is available online. For Teacher Support go to **http://teachers.cie.org.uk** (username and password required).

2.2 Resource lists

We work with publishers providing a range of resources for our syllabuses including textbooks, websites, CDs etc. Any endorsed, recommended and suggested resources are listed on both our public website and on Teacher Support.

The resource lists can be filtered to show all resources or just those which are endorsed or recommended by Cambridge. Resources endorsed by Cambridge go through a detailed quality assurance process and are written to align closely with the Cambridge syllabus they support.

2.3 Training

We offer a range of support activities for teachers to ensure they have the relevant knowledge and skills to deliver our qualifications. See **www.cie.org.uk/events** for further information.

3. Assessment at a glance

- Candidates for Advanced Subsidiary (AS) certification take Papers 1, 2 and 3 (either Advanced Practical Skills 1 or Advanced Practical Skills 2) in a single exam series.
- Candidates who already have AS certification and wish to achieve the full Advanced Level qualification may carry their AS marks forward and take just Papers 4 and 5 in the exam series in which they require certification.
- Candidates taking the complete Advanced Level qualification take all five papers in a single exam series.

Candidates may only enter for the papers in the combinations indicated above.

Candidates may not enter for single papers either on the first occasion or for re-sit purposes.

This syllabus is for:

- candidates for **AS certification only** in either 2013 or 2015,
- candidates carrying forward AS marks and taking Papers 4 and 5 to certificate their full Advanced Level qualification in 2015,
- candidates taking the complete Advanced Level qualification at the end of their course in 2015.

Paper	Type of Paper	Duration	Marks	Weighting	
				AS Level	A Level
1	Multiple Choice	1 hour	40	31%	15%
2	AS Structured Questions	1 hour 15 min	60	46%	23%
3	Advanced Practical Skills 1/2	2 hours	40	23%	12%
4	A2 Structured Questions	2 hours	100		38%
5	Planning, Analysis and Evaluation	1 hour 15 min	30		12%

Paper 1

This paper will consist of 40 multiple choice questions based on the AS syllabus. All questions will be of the direct choice type with four options. Candidates will answer all questions.

Paper 2

This paper will consist of a variable number of structured questions of variable mark value. All the questions will be based on the AS syllabus. Candidates will answer all the questions on the question paper.

Paper 3 – Advanced Practical Skills 1/2

In some examination series, two versions of the Advanced Practical Skills paper will be available, identified as Advanced Practical Skills 1 and Advanced Practical Skills 2. In other series only Advanced Practical Skills 1 will be available.

These papers will be equivalent and each candidate will be required to take only one of them. This is to allow large Centres to split candidates into two groups: one group will take Advanced Practical Skills 1, the other group will take Advanced Practical Skills 2. Each of these papers will be timetabled on a different day.

Each of these practical papers will consist of two approximately equal parts, one of which will require the use of a microscope with low-power and high-power objectives and an eye-piece graticule (see Section 7.2.5 for details). Centres are expected to use eyepiece graticules and stage micrometer scales during teaching. **For the examination, Centres should provide eyepiece graticules as standard. However, Cambridge will supply stage micrometer scales for the examination as needed.**

Candidates will be allowed to use the microscope for a maximum of 1 hour. Candidates will be expected to show evidence of skill in the handling of familiar and unfamiliar biological material. Where unfamiliar materials/techniques are required, full instructions will be given.

Candidates will answer all the questions on the question paper. Although no dissection of materials of animal origin will be set in Advanced Practical Skills papers, dissection, interactive videos or similar will continue to be a useful aid to teaching, e.g. when the heart is being studied.

(Full details are given in Section 6 the Practical Assessment section of the syllabus.)

Paper 4

This paper will consist of two sections.

Section A (85 marks) will consist of a variable number of structured questions of variable mark value, based on the A2 core and the Applications of Biology syllabus.

Section B (15 marks) will consist of a free-response question, presented in an either/or form, that will carry 15 marks based on the A2 core and the Applications of Biology syllabus.

Candidates will answer all questions on the question paper.

Paper 5

This paper will consist of two or more questions based on the practical skills of planning, analysis and evaluation. The examiners will not be restricted by the subject content. Candidates will answer all the questions on the question paper. Questions will require an understanding of the use of statistical tests. The formulae for these tests will be provided. (Full details are given in the Practical Assessment section of the syllabus.)

Availability

This syllabus is examined in the May/June examination series and the October/November examination series.

This syllabus is available to private candidates. However, it is expected that private candidates learn in an environment where practical work is an integral part of the course. Candidates will not be able to perform well in this assessment or progress successfully to further study without this necessary and important aspect of science education.

Detailed timetables are available from **www.cie.org.uk/examsofficers**

Centres in the UK that receive government funding are advised to consult the Cambridge website **www.cie.org.uk** for the latest information before beginning to teach this syllabus.

Combining this with other syllabuses

Candidates can combine this syllabus in an examination series with any other Cambridge syllabus, except syllabuses with the same title at the same level.

4. Syllabus aims and assessment objectives

4.1 Syllabus aims

A course based on this syllabus should aim to:

1 Provide, through well-designed studies of experimental and practical biological science, a worthwhile educational experience for all students, whether or not they go on to study science beyond this level. In particular, it should enable them to:

- become confident citizens in a technological world, with an informed interest in scientific matters;
- recognise the usefulness (and limitations) of scientific method, and its application in other subjects and in everyday life;
- be suitably prepared for studies in biological sciences beyond Cambridge International A Level, in further or higher education, and for professional courses.

2 Develop abilities and skills that:

- are relevant to the study and practice of biological science;
- are useful in everyday life;
- encourage effective, efficient and safe practice;
- encourage effective communication using universal scientific conventions.

3 Develop attitudes relevant to biological science, such as:

- concern for accuracy and precision
- objectivity
- integrity
- skills of enquiry
- initiative
- inventiveness.

4 Stimulate interest in, and care for, the local and global environment, and help students to understand the need for conservation.

5 Make students aware:

- that scientific theories and methods have developed, and continue to develop, as a result of groups and individuals working together, and that biological science overcomes national boundaries;
- that the study and practice of biology are affected and limited by social, economic, technological, ethical and cultural factors;
- that the application of biological science may be both helpful and harmful to the individual, the community and the environment;
- of the importance of using IT for communication, as an aid to experiments and as a tool for interpreting experimental and theoretical results.

6 Stimulate students and give them a lasting interest in biology, so that they find studying biology to be enjoyable and satisfying.

Cambridge International A Level Biology puts great emphasis on understanding and using scientific ideas and principles in different situations, including both those that are well-known to the student and those which are new to them. Cambridge expects that study programmes based on this syllabus will include a variety of learning experiences designed to develop students' skill and comprehension. This will prepare candidates suitably for assessment. It will also allow teachers and students to focus on developing transferable life-long skills that are relevant to the increasingly technological world in which we live.

4.2 Assessment objectives

The three assessment objectives in Cambridge International AS and A Level Biology are:

A: Knowledge with understanding

B: Handling information and solving problems

C: Experimental skills and investigations.

A: Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of:

1 scientific phenomena, facts, laws, definitions, concepts and theories;

2 scientific vocabulary, terminology and conventions (including symbols, quantities and units);

3 scientific instruments and apparatus used in biology, including techniques of operation and aspects of safety;

4 scientific quantities and their determination;

5 scientific and technological applications, with their social, economic and environmental implications.

Questions testing these objectives will often begin with one of the following words: *define*, *state*, *name*, *describe*, *explain (using your knowledge and understanding)* or *outline* (see the glossary of terms in Section 7).

B: Handling information and solving problems

Candidates should be able to handle information and solve problems, using oral, written, symbolic, graphical and numerical forms of presentation. In particular, to:

1 locate, select, organise and present information from a variety of sources;

2 translate information from one form to another;

3 manipulate numerical and other data;

4 use information to identify patterns, report trends and draw conclusions;

5 give reasoned explanations for phenomena, patterns and relationships;

6 make predictions and hypotheses;

7 apply knowledge, including principles, to new situations;

8 demonstrate an awareness of the limitations of biological theories and models;

9 solve problems.

Assessment objectives to do with handling information and solving problems cannot be specified precisely in the syllabus content because questions testing these skills are often based on information that is unfamiliar to the candidate. In answering such questions, candidates must use principles and concepts that are within the syllabus and apply them in a logical, reasoned or deductive manner to a new situation.

Questions testing these objectives will often begin with one of the following words: *discuss*, *predict*, *suggest*, *calculate*, *explain (give reasoned explanations and explain the processes of using information and solving problems)* or *determine* (see the glossary of terms in Section 7).

C: Experimental skills and investigations

Candidates should be able to:

1 follow a detailed set or sequence of instructions;
2 use techniques, apparatus, measuring devices and materials safely and effectively;
3 make and record observations, measurements and estimates, with appropriate regard to precision, accuracy and units;
4 interpret, assess and report on observations and experimental data;
5 assess information, and make predictions and hypotheses;
6 design, plan and carry out experiments and investigations, and identify any problems;
7 choose appropriate techniques, apparatus, measuring devices and materials;
8 assess methods and techniques, and suggest possible improvements.

Full details of the practical assessment are given later in the syllabus.

4.3 Weighting of assessment objectives

The weighting given to the assessment objectives is:

Assessment objective	Weighting (%)	Assessment components
A: Knowledge with understanding	45	Papers 1, 2 and 4
B: Handling information and solving problems	32	Papers 1, 2 and 4
C: Experimental skills and investigations	23	Papers 3 and 5

The weighting table gives a general idea of how marks are allocated to assessment objectives A and B in the theory papers. However, the balance on each paper may vary slightly. Candidates receive 15% of the total marks for awareness of the social, economic, environmental and technological implications and applications of biology. These marks are awarded within the 'Knowledge with understanding' and the 'Handling information and solving problems' categories. Teachers should note that there is a greater weighting of 55% for skills (including handling information, solving problems, practical, experimental and investigative skills), compared to 45% for knowledge and understanding. Teachers should make sure that their schemes of work and the sequence of learning activities reflect this balance, so that the aims of the syllabus are met and the candidates are suitably prepared for the assessment.

4.4 Additional information

Nomenclature
Symbols, signs and abbreviations used in examination papers will follow the recommendations made in Institute of Biology (2009) *Biological Nomenclature* (4th edition) and in ASE (2000) *Signs, Symbols and Systematics: The ASE Companion to 16–19 Science*.

Decimal markers
In accordance with current ASE convention, decimal markers in examination papers will be a single dot on the line. Candidates are expected to follow this convention in their answers.

Modern biological sciences use many concepts from the physical sciences. By the end of the course, candidates should therefore have enough knowledge of the following topics to help them understand biological systems. **No** questions will be set directly on them.

- The electromagnetic spectrum
- Energy changes (potential energy, activation energy and chemical bond energy)
- Molecules, atoms, ions and electrons
- Concentration and molarity
- Acids, bases, pH and buffers
- Isotopes, including radioactive isotopes
- Oxidation and reduction
- Hydrolysis and condensation

5. Syllabus content

The subject content of the syllabus is divided into AS and A2. The A2 section includes a 'Core' and an 'Applications of Biology' section, both of which are studied by all A2 candidates. These are shown in **bold** type in the subject content which is listed according to learning outcomes. The exam is designed to assess the candidate's knowledge and understanding of these outcomes.

5.1 Structure of the syllabus

1 Core syllabus

Cambridge International AS Level candidates will study and be assessed on the first eleven sections, A to K.

Cambridge International A Level candidates will study and be assessed on all sixteen sections, A to P.

- A Cell Structure
- B Biological Molecules
- C Enzymes
- D Cell Membranes and Transport
- E Cell and Nuclear Division
- F Genetic Control
- G Transport
- H Gas Exchange
- I Infectious Disease
- J Immunity
- K Ecology
- **L Energy and Respiration**
- **M Photosynthesis**
- **N Regulation and Control**
- **O Inherited Change** (Gene technology now in section R)
- **P Selection and Evolution**

2 Applications of Biology

Cambridge International AS Level candidates will not be assessed on these sections.

Cambridge International A Level candidates will study and be assessed on all five sections, Q to U.

- **Q Biodiversity and Conservation**
- **R Gene Technology** (includes some material originally in O)
- **S Biotechnology**
- **T Crop Plants**
- **U Aspects of Human Reproduction**

The Applications of Biology section occupies about 12% of the full Advanced Level course. Cambridge provides a booklet covering this section.

So that Cambridge can specify the syllabus as precisely as possible, and also to emphasise the importance of skills other than recall, Learning Outcomes have been used throughout. Each part of the syllabus has a brief **Contents** section followed by detailed **Learning Outcomes**. Cambridge hopes that this format will be helpful to teachers and students. Please note that the syllabus is not intended to be used as a teaching syllabus, nor is it intended to represent a teaching order.

Teachers should include the social, environmental, economic and technological aspects of biology wherever possible throughout the syllabus (see **Aims** 4 and 5 on Page 8). Some examples are included in the syllabus, and teachers should encourage students to apply the principles of these examples to other situations introduced in the course. The number of examples in the syllabus has been limited so that students are not overloaded by factual recall.

Aim 5.4 emphasises the importance of Information Technology in this biology course. Teachers should encourage students to make full use of IT techniques in their practical work. Teachers may also use IT in demonstrations and simulations.

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

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

[PA] next to the learning outcomes in the syllabus content show parts of the subject that are particularly suitable for practical work.

To support Centres in teaching practical skills, Cambridge has produced two detailed booklets. Each contains 30 practical exercises, with at least 10 given in detail, with lesson plans, student worksheets and useful information for teachers and technical support staff. The other 20 are given in outline, so that Centres can develop them and so learn from the experience. The booklets are:

- Teaching AS Biology Practical Skills (PSAS97000105)
- Teaching A2 Biology Practical Skills (PSA297000105)

Centres can order copies from Cambridge publications, 1 Hills Road, Cambridge, CB1 2EU, UK, phone +44 (0) 1223 553553, fax +44 (0) 1223 553558, email **info@cie.org.uk**.

5.2 Core syllabus

A Cell structure

Content

- The microscope in cell studies
- Cells as the basic units of living organisms
- Detailed structure of typical animal and plant cells, as seen using the electron microscope
- Outline functions of organelles in plant and animal cells
- Characteristics of prokaryotic and eukaryotic cells

Learning Outcomes

Candidates should be able to:

(a) **[PA]** use an eyepiece graticule and stage micrometer scale to measure cells and be familiar with units (millimetre, micrometre, nanometre) used in cell studies;

(b) explain and distinguish between resolution and magnification (see section 5), with reference to light microscopy and electron microscopy;

(c) describe and interpret drawings and photographs of typical animal and plant cells, as seen using the electron microscope, recognising the following: rough endoplasmic reticulum and smooth endoplasmic reticulum, Golgi body (Golgi apparatus or Golgi complex), mitochondria, ribosomes, lysosomes, chloroplasts, cell surface membrane, nuclear envelope, centrioles, nucleus, nucleolus, microvilli, cell wall, the large permanent vacuole and tonoplast (of plant cells) and plasmodesmata.
(knowledge that ribosomes occurring in the mitochondria and chloroplasts are 70S (smaller) than those in the rest of the cell (80S) should be included. The existence of small circular DNA in the mitochondrion and chloroplast should be noted);

(d) outline the functions of the structures listed in (c);

(e) **[PA]** compare the structure of typical animal and plant cells;

(f) **[PA]** draw and label low power plan diagrams of tissues and organs (including a transverse section of stems, roots and leaves);

(g) **[PA]** calculate linear magnification of drawings and photographs;

(h) **[PA]** calculate actual sizes of specimens from drawings and photographs;

(i) outline key structural features of typical prokaryotic cells (including: unicellular, 1-5μm diameter, peptidoglycan cell walls, lack of membrane-bound organelles, naked circular DNA, 70S ribosomes) and compare and contrast the structure of prokaryotic cells with eukaryotic cells (reference to mesosomes should not be included);

(j) use the knowledge gained in this section in new situations or to solve related problems.

B Biological molecules

Content

- Structure of carbohydrates, lipids and proteins and their roles in living organisms
- Water and living organisms

Learning Outcomes

Candidates should be able to:

(a) **[PA]** carry out tests for reducing and non-reducing sugars (including using colour standards as a semi-quantitative use of the Benedict's test), the iodine in potassium iodide solution test for starch, the emulsion test for lipids and the biuret test for proteins;

(b) describe the ring forms of α-glucose and β-glucose (candidates should be familiar with the terms *monomer*, *polymer* and *macromolecule*);

(c) describe the formation and breakage of a glycosidic bond with reference both to polysaccharides and to disaccharides including sucrose;

(d) describe the molecular structure of polysaccharides including starch (amylose and amylopectin), glycogen and cellulose and relate these structures to their functions in living organisms;

(e) describe the molecular structure of a triglyceride and a phospholipid and relate these structures to their functions in living organisms;

(f) describe the structure of an amino acid and the formation and breakage of a peptide bond;

(g) explain the meaning of the terms *primary structure*, *secondary structure*, *tertiary structure* and *quaternary structure* of proteins and describe the types of bonding (hydrogen, ionic, disulfide and hydrophobic interactions) that hold the molecule in shape;

(h) describe the molecular structure of haemoglobin as an example of a globular protein, and of collagen as an example of a fibrous protein and relate these structures to their functions (the importance of iron in the haemoglobin molecule should be emphasised. A haemoglobin molecule is composed of 2 alpha (α) chains and 2 beta (β) chains, although when describing the chains the terms α-globin and β-globin may be used. There should be a distinction between collagen molecules and collagen fibres);

(i) describe and explain the roles of water in living organisms and as an environment for organisms;

(j) use the knowledge gained in this section in new situations or to solve related problems.

C Enzymes

Content

- Mode of action of enzymes
- Factors that affect enzyme action

Learning Outcomes

Candidates should be able to:

(a) explain that enzymes are globular proteins that catalyse metabolic reactions;

(b) explain the mode of action of enzymes in terms of an active site, enzyme-substrate complex, lowering of activation energy and enzyme specificity (the lock and key hypothesis and the induced fit hypothesis should be included);

(c) **[PA]** follow the progress of an enzyme-catalysed reaction by measuring rates of formation of products (for example, using catalase) or rates of disappearance of substrate (for example, using amylase);

(d) **[PA]** investigate and explain the effects of temperature, pH, enzyme concentration and substrate concentration on the rate of enzyme-catalysed reactions;

(e) explain the effects of competitive and non-competitive inhibitors on the rate of enzyme activity;

(f) use the knowledge gained in this section in new situations or to solve related problems.

D Cell membranes and transport

Content

- Fluid mosaic model of membrane structure
- Movement of substances into and out of cells

Learning Outcomes

Candidates should be able to:

(a) describe and explain the fluid mosaic model of membrane structure, including an outline of the roles of phospholipids, cholesterol, glycolipids, proteins and glycoproteins;

(b) outline the roles of cell surface membranes;

(c) describe and explain the processes of *diffusion*, *facilitated diffusion*, *osmosis*, *active transport*, *endocytosis* and *exocytosis* (terminology described in the IOB's publication *Biological Nomenclature* should be used; see also section 5; **no** calculations involving water potential will be set);

(d) **[PA]** investigate the effects on plant cells and the effect on animal cells of immersion in solutions of different concentrations of solutions (with different water potentials);

(e) use the knowledge gained in this section in new situations or to solve related problems.

E Cell and nuclear division

Content

- Replication and division of nuclei and cells
- Understanding of chromosome behaviour in mitosis

Learning Outcomes
Candidates should be able to:

(a) explain the importance of mitosis in the production of genetically identical cells, growth, repair and asexual reproduction;

(b) outline the cell cycle, including growth, DNA replication, mitosis and cytokinesis;

(c) **[PA]** describe, with the aid of diagrams, the behaviour of chromosomes during the mitotic cell cycle and the associated behaviour of the nuclear envelope, cell membrane, centrioles and spindle (names of the main stages are expected);

(d) explain how uncontrolled cell division can result in the formation of a tumour and identify factors that can increase the chances of cancerous growth;

(e) explain the meanings of the terms *haploid* and *diploid* (see section 5) and the need for a reduction division (meiosis) prior to fertilisation in sexual reproduction (note: descriptions of homologous chromosomes are not required for AS Level);

(f) use the knowledge gained in this section in new situations or to solve related problems.

F Genetic control

Content

- Structure and replication of DNA
- Role of DNA in protein synthesis

Learning Outcomes
Candidates should be able to:

(a) describe the structure of RNA and DNA and explain the importance of base pairing and the different hydrogen bonding between bases (includes reference to adenine and guanine as purines and to cytosine, thymine and uracil as pyrimidines. Structural formulae for bases is not required but the recognition that purines have a double ring structure and pyrimidines have a single ring structure should be included);

(b) explain how DNA replicates semi-conservatively during interphase;

(c) 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 molecue and state that a mutation is a change in the sequence that may result in an altered polypeptide;

(d) describe the way in which the nucleotide sequence codes for the amino acid sequence in a polypeptide with reference to the nucleotide sequence for HbA (normal) and HbS (sickle cell) alleles of the gene for the β-globin polypeptide;

(e) describe how the information on DNA is used during transcription and translation to construct polypeptides, including the role of messenger RNA (mRNA), transfer RNA (tRNA) and the ribosomes (for genetic dictionaries see section 5);

(f) use the knowledge gained in this section in new situations or to solve related problems.

G Transport

Content

- The need for, and functioning of, a transport system in multicellular plants
- The need for, and functioning of, a transport system in mammals
- Structure and functioning of the mammalian heart

Learning Outcomes

Candidates should be able to:

(a) explain the need for transport systems in multicellular plants and animals in terms of size and surface area to volume ratios;

(b) define the term *transpiration* (see section 5) and explain that it is an inevitable consequence of gas exchange in plants;

(c) **[PA]** describe how to investigate experimentally the factors that affect transpiration rate;

(d) **[PA]** describe the distribution of xylem and phloem tissue in roots, stems and leaves of dicotyledonous plants;

(e) **[PA]** describe the structure of xylem vessel elements, phloem sieve tube elements and companion cells and be able to recognise these using the light microscope;

(f) relate the structure of xylem vessel elements, phloem sieve tube elements and companion cells to their functions;

(g) explain the movement of water between plant cells, and between them and their environment, in terms of water potential (**no** calculations involving water potential will be set);

(h) describe the pathways and explain the mechanisms by which water is transported from soil to xylem and from roots to leaves (includes reference to the symplast/symplastic pathway and apoplast/apoplastic pathway);

(i) outline the roles of nitrate ions and of magnesium ions in plants;

(j) **[PA]** describe how the leaves of xerophytic plants are adapted to reduce water loss by transpiration;

(k) explain translocation as an energy-requiring process transporting assimilates, especially sucrose, between the leaves (sources) and other parts of the plant (sinks);

(l) explain the translocation of sucrose using the mass flow hypothesis;

(m) **[PA]** describe the structures of arteries, veins and capillaries and be able to recognise these vessels using the light microscope;

(n) explain the relationship between the structure and function of arteries, veins and capillaries;

(o) **[PA]** describe the structure of red blood cells, phagocytes (macrophages and neutrophils) and lymphocytes;

(p) state and explain the differences between blood, tissue fluid and lymph;

(q) describe the role of haemoglobin in carrying oxygen and carbon dioxide (including the role of carbonic anhydrase, the formation of haemoglobinic acid and carbaminohaemoglobin);

(r) describe and explain the significance of the oxygen dissociation curves of adult oxyhaemoglobin at different carbon dioxide concentrations (the Bohr effect);

(s) describe and explain the significance of the increase in the red blood cell count of humans at high altitude;

(t) describe the external and internal structure of the mammalian heart;

(u) explain the differences in the thickness of the walls of the different chambers in terms of their functions;

(v) describe the mammalian circulatory system as a closed double circulation;

(w) describe the cardiac cycle (including blood pressure changes during systole and diastole);

(x) explain how heart action is initiated and controlled (reference should be made to the sinoatrial node, the atrioventricular node and the Purkyne tissue);

(y) use the knowledge gained in this section in new situations or to solve related problems.

H Gas exchange and smoking

Content

- The gas exchange system
- Smoking and smoking-related diseases

Learning Outcomes

Candidates should be able to:

(a) **[PA]** describe the structure of the human gas exchange system, including the microscopic structure of the walls of the trachea, bronchioles and alveoli with their associated blood vessels;

(b) **[PA]** describe the distribution of cartilage, ciliated epithelium, goblet cells and smooth muscle in the trachea, bronchi and bronchioles;

(c) describe the functions of cartilage, cilia, goblet cells, mucous glands, smooth muscle and elastic fibres in the gas exchange system;

(d) describe the process of gas exchange between air in the alveoli and the blood;

(e) describe the effects of tar and carcinogens in tobacco smoke on the gas exchange system;

(f) describe the signs and symptoms that enable diagnosis of lung cancer and chronic obstructive pulmonary disease (COPD) (emphysema and chronic bronchitis);

(g) describe the effects of nicotine and carbon monoxide on the cardiovascular system;

(h) explain how tobacco smoking contributes to atherosclerosis and coronary heart disease (CHD);

(i) evaluate the epidemiological and experimental evidence linking cigarette smoking to disease and early death;

(j) discuss the difficulties in achieving a balance between preventions and cure with reference to coronary heart disease, coronary by-pass surgery and heart transplant surgery;

(k) use the knowledge gained in this section in new situations or to solve related problems.

I Infectious disease

Content

- Cholera, malaria, tuberculosis (TB), HIV/AIDS, smallpox and measles
- Antibiotics

Learning Outcomes

Candidates should be able to:

(a) define the term *disease* (see section 5) and explain the difference between an *infectious disease* and non-infectious diseases (limited to sickle cell anaemia and lung cancer; see section 5);

(b) state names and types of causative organism of each of the following diseases: cholera, malaria, TB, HIV/AIDS, smallpox and measles (detailed knowledge of structure is **not** required. For smallpox (Variola) and measles (Morbillivirus) names of genus only is needed);

(c) explain how cholera, measles, malaria, TB and HIV/AIDS are transmitted;

(d) discuss the factors that need to be considered in the prevention and control of cholera, measles, malaria, TB and HIV/AIDS (a detailed study of the life cycle of the malarial parasite is **not** required) (an appreciation of social and biological factors and how economic factors can affect these should be included);

(e) discuss the factors that influence the global patterns of distribution of malaria, TB and HIV/AIDS and assess the importance of these diseases worldwide;

(f) outline the role of antibiotics in the treatment of bacterial infectious diseases (knowledge of specific antibiotics and their mode of action is **not** required);

(g) use the knowledge gained in this section in new situations or to solve related problems.

J Immunity

Content

- The immune system
- Vaccination

Learning Outcomes

Candidates should be able to:

(a) **[PA]** recognise phagocytes and lymphocytes under the light microscope;

(b) state the origin and describe the mode of action of phagocytes (macrophages and neutrophils);

(c) describe the modes of action of B-lymphocytes and T-lymphocytes;

(d) explain the meaning of the term *immune response*, making reference to the terms antigen, self and non-self (see section 5);

(e) explain the role of memory cells in long-term immunity;

(f) relate the molecular structure of antibodies to their functions;

(g) distinguish between *active* and *passive*, *natural* and *artificial immunity* and explain how *vaccination* can control disease (see section 5);

(h) discuss the reasons why vaccination programmes have eradicated smallpox but not measles, tuberculosis (TB), malaria or cholera;

(i) use the knowledge gained in this section in new situations or to solve related problems.

K Ecology

Content

- Levels of ecological organisation
- Energy flow through ecosystems
- Recycling of nitrogen

Learning Outcomes

Candidates should be able to:

(a) define the terms *habitat*, *niche*, *population*, *community* and *ecosystem* and be able to recognise examples of each (see section 5);

(b) explain the terms *autotroph*, *heterotroph*, *producer*, *consumer* and *trophic level* in the context of food chains and food webs (see section 5);

(c) explain how energy losses occur along food chains and discuss the efficiency of energy transfer between trophic levels;

(d) describe how nitrogen is cycled within an ecosystem, including the roles of nitrogen-fixing bacteria (e.g. *Rhizobium*) and nitrifying bacteria (*Nitrosomonas* and *Nitrobacter*);

(e) use the knowledge gained in this section in new situations or to solve related problems.

Note: *An ecosystem should be studied in relation to an area familiar to the candidates.*

L Energy and respiration

Content

- **The need for energy in living organisms**
- **Respiration as an energy transfer process**
- **Aerobic respiration**
- **Anaerobic respiration**
- **The use of respirometers**

Learning Outcomes

Candidates should be able to:

(a) **outline the need for energy in living organisms, as illustrated by anabolic reactions, active transport, movement and the maintenance of body temperature;**

(b) **describe the structure of ATP as a phosphorylated nucleotide;**

(c) **describe the universal role of ATP as the energy currency in all living organisms;**

(d) **explain that the synthesis of ATP is associated with the electron transport chain on the membranes of the mitochondrion;**

(e) **outline glycolysis as phosphorylation of glucose and the subsequent splitting of hexose phosphate (6C) into two triose phosphate molecules, which are then further oxidised with a small yield of ATP and reduced NAD;**

(f) **explain that, when oxygen is available, pyruvate is converted into acetyl (2C) coenzyme A, which then combines with oxaloacetate (4C) to form citrate (6C);**

(g) **outline the Krebs cycle, explaining that citrate is reconverted to oxaloacetate in a series of small steps in the matrix of the mitochondrion (no further details are required);**

(h) **explain that these processes involve decarboxylation and dehydrogenation and describe the role of NAD;**

(i) **outline the process of oxidative phosphorylation, including the role of oxygen (no details of the carriers are required);**

(j) **explain the production of a small yield of ATP from anaerobic respiration and the formation of ethanol in yeast and lactate in mammals, including the concept of oxygen debt;**

(k) **explain the relative energy values of carbohydrate, lipid and protein as respiratory substrates;**

(l) **define the term *respiratory quotient* (RQ) (see section 5);**

(m) **[PA] carry out investigations, using simple respirometers, to measure RQ and the effect of temperature on respiration rate;**

(n) **use the knowledge gained in this section in new situations or to solve related problems.**

M Photosynthesis

Content

- **Photosynthesis as an energy transfer process**
- **The investigation of limiting factors**

Learning Outcomes

Candidates should be able to:

(a) **explain that energy transferred as light is used during the light-dependent stage of photosynthesis to produce complex organic molecules;**

(b) **describe the photoactivation of chlorophyll resulting in the photolysis of water and in the transfer of energy to ATP and reduced NADP (cyclic and non-cyclic photophosphorylation should be described in outline only);**

(c) **describe the uses of ATP and reduced NADP in the light-independent stage of photosynthesis;**

(d) **describe, in outline, the Calvin cycle involving the light-independent fixation of carbon dioxide by combination with a 5C compound (RuBP) to yield two molecules of a 3C compound GP (PGA), and the conversion of GP into carbohydrates, lipids and amino acids (the regeneration of RuBP should be understood in outline only, and a knowledge of CAM plants or the biochemistry of C4 plants is not required);**

(e) **[PA] describe the structure of a dicotyledonous leaf, a palisade cell and a chloroplast and relate their structures to their roles in photosynthesis;**

(f) **[PA] discuss limiting factors in photosynthesis and carry out investigations on the effects of light intensity and wavelength, carbon dioxide and temperature on the rate of photosynthesis;**

(g) **[PA] discuss the role of chloroplast pigments in absorption and action spectra, and separate them using chromatography;**

(h) **use the knowledge gained in this section in new situations or to solve related problems.**

N Regulation and control

Content

- **The importance of homeostasis**
- **Excretion**
- **Control of water and metabolic wastes**
- **Nervous and hormonal communication**
- **Response to changes in the external environment**
- **Regulation of the internal environment**
- **Communication and control in flowering plants**
- **Plant growth regulators**

Learning Outcomes

Candidates should be able to:

(a) **discuss the importance of homeostasis in mammals and explain the principles of homeostasis in terms of receptors, effectors and negative feedback;**

(b) **define the term *excretion* (see section 5) and explain the importance of removing nitrogenous waste products and carbon dioxide from the body;**

(c) **[PA] describe the gross structure of the kidney and the detailed structure of the nephron with the associated blood vessels (candidates are expected to be able to interpret the histology of the kidney, as seen in sections using the light microscope);**

(d) **explain the functioning of the kidney in the control of water by ADH (using water potential terminology) and in the excretion of metabolic wastes;**

(e) **outline the need for communication systems within mammals to respond to changes in the internal and external environment;**

(f) **outline the role of sensory receptors in mammals in converting different forms of energy into nerve impulses;**

(g) **describe the structure of a sensory neurone and a motor neurone and outline their functions in a reflex arc;**

(h) **describe and explain the transmission of an action potential in a myelinated neurone and its initiation from a resting potential (the importance of sodium and potassium ions in the impulse transmission should be emphasised);**

(i) **explain the importance of the myelin sheath (saltatory conduction) and the refractory period in determining the speed of nerve impulse transmission;**

(j) **describe the structure of a cholinergic synapse and explain how it functions (reference should be made to the role of calcium ions);**

(k) **outline the roles of synapses in the nervous system in determining the direction of nerve impulse transmission and in allowing the interconnection of nerve pathways;**

(l) **explain what is meant by the term *endocrine gland* (see section 5);**

(m) **[PA] describe the cellular structure of an islet of Langerhans from the pancreas and outline the role of the pancreas as an endocrine gland;**

(n) **explain how the blood glucose concentration is regulated by negative feedback control mechanisms, with reference to insulin and glucagon;**

(o) **outline the need for, and the nature of, communication systems within flowering plants to respond to changes in the internal and external environment;**

(p) **describe the role of auxins in apical dominance;**

(q) **describe the roles of gibberellins in stem elongation and in the germination of wheat or barley;**

(r) **describe the role of abscisic acid in the closure of stomata;**

(s) **use the knowledge gained in this section in new situations or to solve related problems.**

O Inherited change

Content

- **Passage of information from parent to offspring**
- **Nature of genes and alleles and their role in determining the phenotype**
- **Monohybrid and dihybrid crosses**

Learning Outcomes

Candidates should be able to:

(a) **[PA] describe, with the aid of diagrams, the behaviour of chromosomes during meiosis, and the associated behaviour of the nuclear envelope, cell membrane and centrioles (names of the main stages are expected, but not the sub-divisions of prophase);**

(b) **explain how meiosis and fertilisation can lead to variation;**

(c) **explain the terms *locus*, *allele*, *dominant*, *recessive*, *codominant*, *homozygous*, *heterozygous*, *phenotype* and *genotype* (see section 5);**

(d) **use genetic diagrams to solve problems involving monohybrid and dihybrid crosses, including those involving sex linkage, codominance and multiple alleles (but not involving autosomal linkage or epistasis);**

(e) **use genetic diagrams to solve problems involving test crosses;**

(f) **[PA] 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);**

(g) **explain, with examples, how mutation may affect the phenotype;**

(h) **explain, with examples, how the environment may affect the phenotype;**

(i) **explain how a change in the nucleotide sequence in DNA may affect the amino acid sequence in a protein and hence the phenotype of the organism;**

(j) **use the knowledge gained in this section in new situations or to solve related problems.**

P Selection and evolution

Content

- **Natural and artificial selection**

Learning Outcomes

Candidates should be able to:

(a) **explain how natural selection may bring about evolution;**

(b) **explain why variation is important in selection;**

(c) **explain how all organisms can potentially overproduce;**

(d) **explain, with examples, how environmental factors can act as stabilising or evolutionary forces of natural selection;**

(e) **describe the processes that affect allele frequencies in populations with reference to the global distribution of malaria and sickle cell anaemia;**

(f) **explain the role of isolating mechanisms in the evolution of new species;**

(g) **describe one example of artificial selection;**

(h) **use the knowledge gained in this section in new situations or to solve related problems.**

5.3 Applications of Biology

Teachers will find it helpful to refer to Cambridge's *Applications of Biology* book when teaching this section. This is available from the Cambridge Teacher Support website and from Cambridge Publications, and provides a guide to the level of detail required. The Applications of Biology section of the syllabus forms approximately one-eighth of the A Level material examined.

Q Biodiversity and conservation

Content

- **Classification**
- **Conservation issues**

Learning Outcomes

Candidates should be able to:

(a) **[PA] outline the five-kingdom classification to illustrate the diversity of organisms (cross reference to Syllabus Section A (c) and A (g), a knowledge of phyla within the kingdoms is not required);**

(b) **discuss the meaning of the term biodiversity;**

(c) **discuss the reasons for the need to maintain biodiversity;**

(d) **describe the reasons why one named species has become endangered, and use this information in the context of other endangered species;**

(e) **discuss methods of protecting endangered species, including the roles of zoos, botanic gardens, conserved areas (national parks) and seed banks;**

(f) **use the knowledge gained in this section in new situations or to solve related problems.**

R Gene technology

Content

- **Gene technology for insulin production**
- **Markers for genetic engineering**
- **Benefits and hazards of gene technology**
- **DNA sequencing and genetic fingerprinting**
- **Cystic fibrosis**
- **Genetic screening and genetic counselling**

Learning Outcomes

Candidates should be able to:

(a) **describe the steps involved in the production of bacteria capable of synthesising human insulin:**
  - **identifying the human insulin gene**
  - **isolating mRNA and making cDNA using reverse transcriptase**
  - **cloning the DNA using DNA polymerase**
  - **inserting the DNA into a plasmid vector using restriction enzymes and DNA ligase**
  - **inserting the plasmid vector into the host bacterium**
  - **identifying genetically modified bacteria using antibiotic resistance genes**
  - **cloning the bacteria and harvesting the human insulin;**

(b) **explain the advantages of treating diabetics with human insulin produced by gene technology;**

(c) **explain why promoters need to be transferred along with desired genes in gene technology;**

(d) **explain why and how genes for enzymes that produce fluorescent or easily stained substances are now used instead of antibiotic resistance genes as markers in gene technology;**

(e) **describe the benefits and hazards of gene technology, with reference to specific examples;**

(f) **discuss the social and ethical implications of gene technology;**

(g) **[PA] outline the principles of electrophoresis as used in:**

- **genetic fingerprinting**
- **DNA sequencing;**

(h) **describe the causes and outline the symptoms of cystic fibrosis (CF) as an example of a recessive genetic condition (reference should be made to CFTR protein). Issues related to CF will need to be handled with sensitivity;**

(i) **describe the progress towards successful gene therapy for CF;**

(j) **discuss the roles of genetic screening for genetic conditions and the need for genetic counselling;**

(k) **use the knowledge gained in this section in new situations or to solve related problems.**

S Biotechnology

Content

- **Industrial applications of microorganisms**
- **Batch and continuous culture**
- **Penicillin as an antibiotic**
- **Immobilisation of enzymes**
- **Monoclonal antibodies**

Learning Outcomes

Candidates should be able to:

(a) **outline the use of microorganisms in the extraction of heavy metals from low grade ores;**

(b) **explain what is meant by the terms *batch culture* and *continuous culture* (see section 5);**

(c) **compare the advantages and disadvantages of batch and continuous culture with reference to the production of secondary metabolites (e.g. penicillin), enzymes (e.g. protease) and biomass (e.g. mycoprotein);**

(d) **describe, for penicillin as an example of an antibiotic:**

- **the mode of action on bacteria and why it does not affect viruses**
- **causes and effects of antibiotic resistance;**

(e) **[PA] immobilise an enzyme in alginate and compare the ease of recovering the enzyme and ease of purification of the product compared to the same enzyme that has not been immobilised;**

(f) **explain the principles of operation of dip sticks containing glucose oxidase and peroxidase enzymes, and biosensors that can be used for quantitative measurement of glucose;**

(g) **outline the hybridoma method for the production of a monoclonal antibody**

(h) **evaluate the use of monoclonal antibodies compared to conventional methods for diagnosis and treatment of disease, and testing for pregnancy;**

(i) **use the knowledge gained in this section in new situations or to solve related problems.**

T Crop plants

Content

- **Crop plant reproduction**
- **Crop adaptations**
- **Methods to improve crops**

Learning Outcomes

Candidates should be able to:

(a) **[PA] describe and explain the structural features of a named, wind-pollinated plant;**

(b) **compare the outcomes of self-pollination and cross-pollination in terms of genetic variation;**

(c) **[PA] describe the structure of the fruit in maize and explain the function of the endosperm;**

(d) **explain the significance of the grains of cereal crops in the human diet;**

(e) **[PA] explain how the anatomy and physiology of the leaves of C4 plants such as maize or sorghum are adapted for high rates of carbon fixation at high temperatures in terms of:**

- **the high optimum temperatures of the enzymes involved**
- **the spatial separation of initial carbon fixation from the light-dependent stage (biochemical details of the C4 pathway are not required);**

(f) **[PA] explain how sorghum is adapted to survive in arid environments;**

(g) **[PA] explain how rice is adapted to grow with the roots submerged in water in terms of tolerance to ethanol and presence of aerenchyma;**

(h) **outline the following examples of crop improvement by conventional breeding techniques:**

- **hybridisation leading to polyploidy in wheat**
- **inbreeding and hybridisation in producing vigorous, uniform maize;**

(i) **outline the following examples of crop improvement by genetic modification and include any associated detrimental effects on the environment or economy:**

- **herbicide-resistant oil seed rape**
- **insect-resistant maize and cotton**
- **Vitamin A enhanced rice;**

(j) **use the knowledge gained in this section in new situations or to solve related problems.**

U Aspects of human reproduction

Content

- **Gametogenesis**
- **Roles of hormones in the menstrual cycle**
- **Controlling human reproduction**

Learning Outcomes

Candidates should be able to:

(a) **[PA] describe the histology of the mammalian ovary and testis;**

(b) **outline gametogenesis in a male and female human as a process involving mitosis, growth, meiosis and maturation;**

(c) **explain the role of hormones in maintenance of the human menstrual cycle, and link this to the changes in the ovary and uterus during the cycle;**

(d) **outline the biological basis of the effect of oestrogen/progesterone contraceptive pills;**

(e) **discuss and evaluate the biological, social and ethical implications of the use of contraception**

(f) **outline the technique of in-vitro fertilisation (IVF) and discuss its ethical implications;**

(g) **use the knowledge gained in this section in new situations or to solve related problems.**

6. Definitions

This section contains definitions and factual information for supporting teaching, learning and assessment of biology within this syllabus. The information is set out in the form that the examiners believe best reflects current understanding of biology. This information will be reflected in setting the exam papers.

As a specific example: there are a variety of ways of presenting the genetic code (here termed *genetic dictionaries*). This glossary defines the genetic dictionaries that will be used in setting any exam question for the papers to which this syllabus refers. Candidates are expected to be familiar with the use of these dictionaries rather than others, and are normally expected to give answers in terms of these dictionaries. If a candidate uses a different dictionary in an answer to a question, they will be given credit, provided that the candidate makes it clear to the examiner which dictionary they used, and provided that the answers are correct.

Active immunity: immunity resulting from exposure to an antigen. During the subsequent immune response, antibodies are produced by plasma cells and the body makes memory cells that provide ongoing long-term immunity. There is a delay before the immune response is complete, so immunity takes some days to build up.

Allele: one of two or more alternative nucleotide sequences at a single gene locus, so alleles are variant forms of a gene. For example, the alleles of the ABO blood group gene are found at a locus on chromosome 9, with the alleles including I^A, I^B and I^O. Diploid body cells contain two copies of each homologous chromosome, so have two copies of chromosome 9, and so have two copies of the gene. These may be the same allele (homozygous), for example I^A I^A, or I^B I^B or I^O I^O, or they may be different alleles (heterozygous), for example I^A I^B, or I^A I^O or I^B I^O. The gene for producing the haemoglobin β-polypeptide has a number of alleles. Two of these are the normal allele Hb^A and the sickle cell allele, Hb^S, giving Hb^A Hb^A and Hb^S Hb^S as homozygous genotypes and Hb^A Hb^S as a heterozygous genotype.

Antibody: A glycoprotein secreted by a plasma cell. An antibody binds to the specific antigen that triggered the immune response, leading to destruction of the antigen (and any pathogen or other cell to which the antigen is attached). Antibodies have regions that vary in shape (variable regions) that are complementary to the shape of the antigen. Some antibodies are called antitoxins and prevent the activity of toxins ('prevent the activity of' is sometimes called neutralise, which does **not** mean that this is anything to do with pH).

Antigen: a protein (normally – some carbohydrates and other macromolecules can act as antigens) that is recognised by the body as foreign (so as non-self) and that stimulates an immune response. The specificity of antigens (which is a result of the variety of amino acid sequences that are possible) allows for responses that are customised to specific pathogens.

Artificial immunity: immunity that is acquired by a person as a result of medical intervention. This includes artificial passive immunity following injection of antibodies (for example monoclonal antibodies, to treat acute life-threatening infections, such as tetanus or rabies). It also includes the long-term immunity that results from the injection of antigens (such as those attached to killed or weakened pathogens) where memory cells are made.

Batch culture: a method of culturing organisms in which all the components are added at the beginning. A batch culture uses a container with a growing population of organisms (for example of microorganisms suspended in a fermenter or fish in a pond) where there is a limited supply of raw materials. Population growth follows a sigmoid pattern and there is a total harvest of the contents of the container.

Codominant: alleles that are both expressed if they are present together in a heterozygous person. For example, alleles I^A and I^B of the ABO blood group gene are codominant. Therefore, in a heterozygous person, $I^A I^B$, both alleles are expressed and the blood group is AB. In the case of the haemoglobin β-polypeptide gene, codominance means that the phenotype of a person who has $Hb^A Hb^A$ is unaffected by sickle cell disorder, the phenotype of a person who has $Hb^A Hb^S$ is the less severe sickle cell trait and the phenotype of a person who has $Hb^S Hb^S$ is the more severe sickle cell anaemia.

Community: all of the populations of all of the different species within a specified area at a particular time.

Confidence limit: the range in which a population value is likely to fall. This is usually taken as 95% of the time a measurement will fall in this range. In a normally distributed population, the observed value falls in the middle of the confidence limits.

Consumers: heterotrophic organisms that get energy-rich organic compounds by eating or decomposing other organisms. They exist at the second (e.g. herbivore) or higher (e.g. carnivore) trophic levels in food chains.

Continuous culture: a method of culturing organisms using a container with a growing population of organisms (for example of microorganisms suspended in a fermenter or fish in a pond) that is continuously supplied with new raw materials and continuously harvested in order to keep the culture in exponential population growth.

Decomposers: saprotrophic organisms that feed on dead organisms and organic waste (such as dead leaves or faeces), releasing nutrients for re-use and so playing an important role in the carbon and nitrogen cycle.

Dependent variable: the variable in an experiment or investigation that is measured.

Diffusion: the net movement of particles such as molecules from a region where they are at a higher concentration to a region with a lower concentration, using energy from the random movements of particles. This includes diffusion of small non-polar molecules (such as oxygen and carbon dioxide) through the cell membranes, as well as diffusion of fat-soluble molecules (such as vitamin A) through the cell surface membrane.

Diploid: a eukaryotic cell or organism containing two complete sets of chromosomes (two copies of each homologous chromosome), shown as 2n, such as a human body (somatic) cell.

Disease: an abnormal condition affecting an organism, which reduces the effectiveness of the functions of the organism.

Dominant: an allele with a phenotype that is expressed even when present with an allele that is recessive to it. For example, in the ABO blood group gene, I^A is dominant to I^O. Therefore a person with the genotype $I^A I^O$ has blood group A because only the dominant allele is expressed.

Ecology: the study of the inter-relationships between organisms and all living (biotic) and non-living (abiotic) components of their environment.

Ecosystem: a unit made up of biotic and abiotic components interacting and functioning together, including all the living organisms of all types in a given area and all the abiotic physical and chemical factors in their environment, linked together by energy flow and cycling of nutrients. Ecosystems may vary in size but always form a functional entity: for example, a decomposing log, a pond, a meadow, a reef, a forest, or the entire biosphere.

Endocrine gland: a gland containing specialised secretory cells that release a hormone into the blood stream at a distance from the hormone's target organ.

Endocytosis: uptake of materials into cells by inward foldings of the cell membrane to form sacs of membrane that separate from the cell membrane to form vesicles within the cytoplasm, using energy from ATP to move the cytoplasm around. The process may involve liquid solutions/suspensions (pinocytosis) or solid macromolecules or cells (phagocytosis).

Environment: the external conditions, resources and stimuli with which organisms interact, affecting their life, development and survival.

Excretion: the elimination from the body of waste compounds produced during the metabolism of cells, including, for a human, carbon dioxide (excreted through the lungs) and urea (excreted through the kidneys in urine).

Exocytosis: secretion of materials out of cells by cytoplasmic vesicles fusing with the cell membrane and releasing the contents of the vesicle into the fluid around the cell, using ATP to move the cytoplasm.

Facilitated diffusion: the diffusion of ions and polar (water-soluble) molecules through cell membranes using specific protein channels or carriers, down a concentration gradient (from regions where they are at higher concentration to regions where they are at lower concentration).

Genetic dictionary: a list of the particular base sequences that correspond with particular amino acids. This will vary depending on whether mRNA, tRNA or either of the two DNA base sequences is given.

Candidates should be able to transcribe DNA triplet codes to mRNA codons and to translate mRNA codons to tRNA anticodons and on to amino acid sequences, using provided excerpts of mRNA and DNA dictionaries, which use abbreviated names of amino acids as shown below. Candidates do **not** need to recall specific codes or names of amino acids.

The genetic dictionaries that will be used are given below:

mRNA genetic dictionary

		2nd base			
1st base		U	C	A	G
	U	UUU Phe UUC Phe UUA Leu UUG Leu	UCU Ser UCC Ser UCA Ser UCG Ser	UAU Tyr UAC Tyr UAA *Stop* UAG *Stop*	UGU Cys UGC Cys UGA *Stop* UGG Trp
	C	CUU Leu CUC Leu CUA Leu CUG Leu	CCU Pro CCC Pro CCA Pro CCG Pro	CAU His CAC His CAA Gln CAG Gln	CGU Arg CGC Arg CGA Arg CGG Arg
	A	AUU Ile AUC Ile AUA Ile AUG Met	ACU Thr ACC Thr ACA Thr ACG Thr	AAU Asn AAC Asn AAA Lys AAG Lys	AGU Ser AGC Ser AGA Arg AGG Arg
	G	GUU Val GUC Val GUA Val GUG Val	GCU Ala GCC Ala GCA Ala GCG Ala	GAU Asp GAC Asp GAA Glu GAG Glu	GGU Gly GGC Gly GGA Gly GGG Gly

The DNA genetic dictionaries that are available consist of two types, depending on which strand of DNA is reported. Many researchers and teachers use a dictionary that includes DNA codes that are complementary to the mRNA codons shown above. During transcription, it is this strand that is used as a template to make the mRNA. All Cambridge publications (including this syllabus and the exam questions associated with it) use this DNA dictionary. It is shown below.

DNA genetic dictionary (showing triplet codes that are complementary to mRNA codons)

		2nd base			
1st base		A	G	T	C
	A	AAA Phe AAG Phe AAT Leu AAC Leu	AGA Ser AGG Ser AGT Ser AGC Ser	ATA Tyr ATG Tyr ATT *Stop* ATC *Stop*	ACA Cys ACG Cys ACT *Stop* ACC Trp
	G	GAA Leu GAG Leu GAT Leu GAC Leu	GGA Pro GGG Pro GGT Pro GGC Pro	GTA His GTG His GTT Gln GTC Gln	GCA Arg GCG Arg GCT Arg GCC Arg
	T	TAA Ile TAG Ile TAT Ile TAC Met	TGA Thr TGG Thr TGT Thr TGC Thr	TTA Asn TTG Asn TTT Lys TTC Lys	TCA Ser TCG Ser TCT Arg TCC Arg
	C	CAA Val CAG Val CAT Val CAC Val	CGA Ala CGG Ala CGT Ala CGC Ala	CTA Asp CTG Asp CTT Glu CTC Glu	CCA Gly CCG Gly CCT Gly CCC Gly

Sense/antisense will **not** be used in this syllabus in the context of DNA and mRNA because these terms have become ambiguous.

Genotype: the particular alleles of a gene at the appropriate locus on both copies of the homologous chromosomes of its cells (for example, $I^A I^B$). It is sometimes described as the genetic constitution of an organism with respect to a gene or genes.

Habitat: the particular location and type of local environment occupied by a population or organism, characterised by its physical features or by its dominant producers (such as rocky shore or sugar cane field).

Haploid: a eukaryotic cell or organism containing only one complete set of chromosomes (only one of each homologous chromosome), shown as n, such as a human sperm or secondary oocyte.

Heterozygous: a term describing a diploid organism that has different alleles of a gene at the gene's locus on both copies of the homologous chromosomes in its cells (e.g. Hb^A Hb^S) and therefore produces gametes with two different genotypes (0.5 Hb^A and 0.5 Hb^S). A heterozygote is an organism that is heterozygous.

Homozygous: a term describing a diploid organism that has the same allele of a gene at the gene's locus on both copies of the homologous chromosomes in its cells (e.g. Hb^A Hb^A) and therefore produces gametes with identical genotypes (all Hb^A). A homozygote is an organism that is homozygous.

Immune response: the complex series of reactions of the body to an antigen, such as a molecule on the outside of a bacterium, virus, parasite, allergen or tumour cell.

- The immune response begins with an innate first response, carried out by phagocytic white blood cells, which can destroy and engulf (by phagocytosis/endocytosis) many different foreign organisms.
- At the same time, the primary phase of the adaptive immune system response begins, in which specific clones of B-lymphocytes and T-lymphocytes divide and differentiate to form antibody-secreting plasma cells (from B-lymphocytes) and T helper cells and T killer cells (from T-lymphocytes) that are specific to the antigen, contributing to its destruction or preventing its activity.
- This leads into the secondary phase of the adaptive immune system response, where memory cells retain the capability to secrete antibodies or act as T helper or T killer cells as soon as the specific antigen is detected again.

Independent variable: the variable in an experiment or investigation that is manipulated or changed.

Infectious disease: a disease caused by a pathogen that can be transmitted from one host organism to another.

Locus: the position of a gene or other specific piece of DNA (such as a marker) on a chromosome. The same gene is always found at the same locus of the same chromosome (unless there has been a mutation). The locus is designated by the chromosome number, its arm, and its place. For example, the gene associated with ABO blood groups is at locus 9q34, meaning the gene is found on chromosome 9, on the long arm (q) at region 34. The gene associated with sickle cell anaemia is at locus 11p15.5, meaning chromosome 11, short arm (p), region 15.5.

Magnification: the size of an image of an object compared to the actual size. It is calculated using the formula M = I/A (M is magnification, I is the size of the image and A is the actual size of the object, using the **same units** for both sizes). This formula can be rearranged to give the actual size of an object where the size of the image and magnification are known: A = I/M.

Natural immunity: immunity that is acquired by the individual as a natural part of their life. This includes natural passive immunity following transfer of maternal antibodies into a fetus through the placenta and into a newborn infant in the first milk (colostrum). It also includes the natural active immunity that follows natural infection by a pathogen involving the production of memory cells (for example, natural infection with chicken pox, giving long-term protection from this virus).

Niche: the functional role or place of a species of organism within an ecosystem, including interactions with other organisms (such as feeding interactions), habitat, life-cycle and location, adding up to a description of the specific environmental features to which the species is well adapted.

Non-infectious disease: a disease with a cause other than a pathogen, including genetic disorders (such as sickle cell anaemia) and lung cancer (linked to smoking and other environmental factors).

Non-self: proteins (normally, but see **antigen**) that contain sequences of amino acids that are not the same as any self proteins and that can be recognised by immune system cells and can trigger an immune response in the body. Sometimes these are termed non-self antigens. When cells are infected by an antigen, or become cancerous, some of their antigens may be changed from self to non-self.

Osmosis: the diffusion of water molecules from a region where water is at a higher water potential through a partially permeable membrane to a region with a lower water potential.

Passive immunity: immunity involving the transfer of antibodies (already made in the body of another organism or *in vitro*) into the body where they will bind to their specific antigen if it is present. This gives instant immunity but does not lead to the development of memory cells, so the immunity only lasts for a few weeks.

Pathogen: a biological agent (such as a virus, bacterium, fungus or protoctist) that causes disease. A pathogen causing human diseases will have, as part of its structure, proteins that are different from those of the human host and are therefore antigens.

Phenotype: the physical, detectable expression of the particular alleles of a gene or genes present in an individual. It may be possible to see the phenotype (e.g. human eye colour) or tests may be required (e.g. ABO blood group). When the phenotype is controlled by a small number of alleles of a particular gene, it may be genetically determined (e.g. human eye colour), giving rise to **discontinuous variation**. When the phenotype is controlled by the additive effects of many genes (polygenic), it may be affected by the environment as well as genes (e.g. human height), giving rise to **continuous variation.**

Population: all of the organisms of one particular species within a specified area at a particular time, sharing the same gene pool and more or less isolated from other populations of the same species.

Producers: autotrophic organisms, at the first trophic level in food chains, which can use simple inorganic compounds (such as carbon dioxide and inorganic nitrogen) plus energy from light (photosynthesis) or oxidation of inorganic chemicals (chemosynthesis) to manufacture energy-rich organic compounds.

Recessive: an allele with a phenotype that is not expressed when an allele that is dominant to it is present. For example, I^O is recessive to I^A, so a person with the genotype $I^A\ I^O$ has blood group A, and a person can only be blood group O if they are homozygous recessive, $I^O\ I^O$.

Reliability: reliable results are repeatable by the same student and reproducible by others.

Resolution: ability of a microscope to distinguish two objects as separate from one another. The smaller and closer together the objects that can be distinguished, the higher the resolution. Resolution is determined by the wavelength of the radiation used to view the specimen. If the parts of the specimen are smaller than the wavelength of the radiation, then the waves are not stopped by them and they are not seen. Light microscopes have limited resolution compared to electron microscopes because light has a much longer wavelength than the beam of electrons in an electron microscope.

Respiratory quotient, **RQ**: the volume of carbon dioxide produced divided by the volume of oxygen used during respiration.

It can also be determined theoretically by calculation:

$$RQ = \frac{CO_2 \text{ produced}}{O_2 \text{ used}}$$

e.g. for a carbohydrate: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

$$RQ = \frac{6}{6} = 1$$

e.g. for a lipid: $2C_{57}H_{110}O_6 + 163O_2 \rightarrow 114CO_2 + 110H_2O$

$$RQ = \frac{114}{163} = 0.7$$

Self: the products of the body's own genotype, which contain proteins (normally, but see **antigen**) that do not trigger an immune response in the body's own immune system. Inside the body that produced them, self proteins do not act as antigens (and so do not stimulate an immune response) but, if introduced into another body, they become non-self.

Species: a group of organisms that are reproductively isolated, interbreeding to produce fertile offspring. Organisms belonging to a species have morphological (structural) similarities, which are often used to identify to which species they belong.

Standardised (controlled) variables: the variables in an experiment or investigation that are kept the same so they do not influence the measurement of the dependent variable.

Standard deviation: the spread of a set of data from the mean of the sample is a measure of the variability of a population from a sample. A small standard deviation indicates that the data is more reliable.

Standard error: an estimate of the reliability of the mean of a population sample. A small standard error indicates that the mean value is close to the actual mean of the population.

Transpiration: the process through which water vapour is lost from the aerial parts of plants. It occurs as the result of evaporation of water at the surface of mesophyll cells into the airspaces within the leaf, followed by diffusion of water vapour out of the leaf, mainly through stomata, down a water potential gradient from the surface of spongy mesophyll cells via airspaces in the leaf to the atmosphere.

Trophic level: a position in a food chain, indicating the numbers of energy-transfer steps to that level. Producers are at trophic level 1, herbivores are at trophic level 2, and so on, up to trophic level 5 for some large predators such as polar bear and orca.

Vaccination: the medical giving of material containing antigens, but with reduced or no ability to be pathogens, in order to give long-term active immunity as a result of the production of memory cells.

Validity: valid results are reliable and successful at measuring the intended dependent variable.

7. Practical assessment

7.1 Introduction

Candidates should have opportunities to practise experimental skills throughout their course of study. As a guide, candidates should spend at least 20% of their time doing practical work individually or in small groups. This 20% does not include the time spent observing teacher demonstrations of experiments and simulations. The practical work that candidates carry out during their course should:

- provide learning opportunities so that candidates develop the skills they need to carry out experimental and investigative work;
- reinforce the theoretical subject content of the syllabus;
- introduce an understanding of how experiment and theory interact in scientific method;
- be enjoyable, contributing to candidates' motivation.

Candidates' experimental skills are assessed in Papers 3 (Advanced Practical Skills 1/2) and 5. In each of these papers, the examiners are not strictly bound by the subject content of the syllabus when finding contexts for setting questions. Within unfamiliar contexts, candidates are told exactly what to do and how to do it. Within familiar contexts listed in the syllabus, the candidates are expected to know how to use the techniques. Knowledge of theory and experimental skills will only be drawn from within the syllabus. Examples of unfamiliar contexts might include:

- following instructions to set up and use unfamiliar equipment such as a simple respirometer;
- making microscopic observations, drawings and magnification calculations from unfamiliar structures of specimens;
- following instructions to use unfamiliar biochemical procedures.

7.2 Paper 3 – Advanced Practical Skills 1/2

In some examination series, two versions of the Advanced Practical Skills paper will be available, identified as Advanced Practical Skills 1 and Advanced Practical Skills 2. These papers will contain different questions, but will be equivalent in the skills assessed and in the level of demand. Each candidate should take one of these papers.

Where two versions of the paper are offered, some schools may wish to divide their candidates so that some are entered for Advanced Practical Skills 1 and the others are entered for Advanced Practical Skills 2; other schools may wish to enter all of their candidates for the same paper.

Paper 3 (Advanced Practical Skills 1/2) is a timetabled, laboratory-based practical paper that focuses on the following experimental skills:

- manipulating apparatus;
- data presentation;
- analysis and evaluation.

Each paper:

- has two or more questions;
- has two roughly equal parts so that Centres can provide microscopes for half of the candidates at a time;
- includes an experiment or experiments requiring candidates to collect quantitative or qualitative data, to draw up tables, charts, graphs and other appropriate means of presenting the data, and to analyse it to make appropriate conclusions;
- requires candidates to make observations of specimens, to display their observations appropriately and to make appropriate analyses, including making calculations, deductions and conclusions from the observations;
- includes questions set in different areas of AS Biology, and may include material from unfamiliar contexts (see above).

7.2.1 Mark scheme for Paper 3 (Advanced Practical Skills 1/2)

Paper 3 is marked using the mark scheme shown in the table. The sections following the table list the expectations for each mark category.

Skill	Total marks	Breakdown of marks	
Manipulation, measurement and observation (MMO)	16 marks	Successfully collecting data and observations	8 marks
		Making decisions about measurements or observations	8 marks
Presentation of data and observations (PDO)	12 marks	Recording data and observations	4 marks
		Displaying calculations and reasoning	2 marks
		Data layout	6 marks
Analysis, conclusions and evaluation (ACE)	12 marks	Interpreting data or observations and identifying sources of error	6 marks
		Drawing conclusions	3 marks
		Suggesting improvements	3 marks

7.2.2 Development of skills in investigations:

- Manipulation, measurement and observation MMO– decisions about variables and risk assessment in investigations and collection of results
- Presentation of results PDO– recording results, display of calculations from data with reasoning and data layout (graphs)
- Analysis, conclusions and evaluation ACE – analysis and interpretation of results and identifying sources of error, drawing conclusions and suggesting improvements or modifications to extend the investigation

MMO – Manipulation (use of experimental techniques) Measurements and Observations:

MMO decisions, within a given investigation the procedure should allow candidates to learn to:

(a) Identify the independent and dependent variables in investigations carried out by candidates. Where appropriate, investigations should identify the independent and dependent variables.

(b) Describe how the **independent variable** has been changed within a suitable range to provide accurate results.

(i) decide the range and how to change an independent variable, including:

- concentration – from maximum provided to suitable minimum
- temperature – practical range above freezing and up to 100°C by maintaining water-baths – thermostatically controlled or using cold water and heating or mixing cold and hot water.
- pH – using buffers in a suitable range
- light intensity – using distance of lamp
- windspeed – using distance of fan
- humidity – using plastic bag or calcium hydroxide

(ii) decide number of values at which measurements are recorded:
This may be either at least 5 values (ideally), or may require repeats or replicates or more measurements around a particular value

(iii) decide intervals – even intervals or more in one region, including:

- concentration – using serial dilution by half or factor of ten or by simple dilution using regular intervals, e.g. 10%, 8%, 6%, 4%, 2%.
- temperature – change by 5°C or 10°C or more temperatures around expected optimum
- pH – whole numbers between pH 3 and pH 10 or 0.5 changes or closer around a particular pH to obtain an optimum

(iv) decide how to identify the presence and estimate the quality of biological molecules using biochemical tests

(c) Describe a control if appropriate.

(i) use of zero concentration of a molecule and replace with the same volume with water

(ii) enzyme control – denature enzyme by boiling or remove enzyme and replace with equal volume of distilled water

(iii) remove plant and replace with porous pot

(d) Decide which variables have been standardised and describe how to standardise each variable to provide accurate results.

(i) for a particular investigation decide which variables have been standardised because they may change the results if the variable changes during the investigation

(ii) volume – describe practical volumes to use in apparatus, for example test-tubes or beakers

(iii) concentration

(iv) temperature

(v) pH – buffers

(vi) biological material, for example plant material – different phenotype or genotype; age; storage conditions; time of year; mass; volume; position in, e.g. potato; or animal material; phenotype or genotype; age; sex; mass

(vii) windspeed/draughts: enclose apparatus or sensible suggestion

(viii) humidity: in enclosed environment

(ix) apparatus – test-tube sizes; airtight.

(e) Using the skills, knowledge and understanding of the AS Biology syllabus, decide and describe how the dependent variable has been measured to obtain accurate and reliable results.

Use a variety of techniques to measure dependent variables, for example:

(i) release of gases: count number of bubbles; measure volume of displaced water or collected in a gas syringe; change in distance of a liquid in a manometer or capillary delivery tube; change in indicator/litmus paper colour or removal of colour in indicator or cloudiness; comparison to colour standard or chart or colorimeter

(ii) absorption of gases; change in distance of a liquid in a manometer or capillary delivery tube; change in indicator/litmus paper colour or removal of colour in indicator; comparison to colour standard or chart or colorimeter

(iii) length – mm ruler, 2 mm graph paper vernier callipers

(iv) colour changes for example in biochemical tests: colour standards of known concentrations, colorimeter; or indicator colour changes

(v) use of a microscope for counting or recording plasmolysed cells or use of grid/haemocytometer

Decide on:

(i) frequency of measurement, for example initial rate of reaction should be conducted as quickly as possible

(ii) how long to leave running, for example, rate of reaction might be expected to be constant over several minutes or colour changes may take several minutes to occur, in which case leaving to run for as long as possible may be appropriate

(iii) reaching an end-point investigation needs to run long enough to reach this end-point

(iv) repeat or replicate readings, for example to obtain a mean or to repeat an anomalous result or to provide a more accurate estimate

(v) how to count a large number by sampling or in grid (count those touching top and left ignore those touching bottom and right)

(vi) how to measure area using a grid, counting those half or more within grid as one whole square and those squares less than half are not counted.

MMO collection – within a given investigation the procedure should allow candidates to learn to:

(a) Follow instructions or diagrams to collect results and assess the risk of a procedure.

Use a range of investigations to collect results.

Risk assessment:

- Low risk: use of low risk apparatus and chemicals for example use of potometers and cutting shoots or stains such as methylene blue.
- Medium risk: use of heating of water-baths and chemicals which might be harmful or irritant for example Iodine in potassium iodide, Benedict's solution, Biuret reagent(s), dilute hydrochloric acid.
- High risk: use of high concentrations of acids and alkalis.

(b) Make readings using a range of apparatus to obtain accurate and reliable results or observations.

Quantitative results from readings of, for example:

(i) thermometers, e.g. temperature changes with time

(ii) mm ruler, e.g. distance with time

(iii) stop clock/stop watch, e.g. time for change/collection of a set volume

(iv) tally counts of numbers, e.g. bubbles in a minute

(v) protractors, e.g. angle of bend

(vi) balances, e.g. to 0.1 g mass

(vii) measuring cylinders or different sizes of syringes, e.g. volumes of solutions

(viii) grids or microscope slides, e.g. numbers of plants in an area or plasmolysed cells

When recording data and observations, if a candidate gives one measurement of length to the nearest millimetre in a column of raw data, then they should give all the lengths in that column to the nearest millimetre. The degree of precision should be appropriate for the measuring instrument used. A candidate should not record a distance measured on a millimetre scale as '2 cm'. Where the calibration marks on a measuring instrument are widely spaced, the candidate may need to interpolate between the marks. Where the calibration marks are close together, then the candidate should take the reading to the nearest calibration mark. Centres can find more information on measurement at **www.rsc.org/images/RSCmeasurements_teacher_tcm18-189111.pdf**

Qualitative results from observations of:

(viii) clear description of colour changes; for example 'blue' or 'orange' or purple'. Where fine discrimination is required, then use of 'pale' or dark'
Use of different numbers of +++ or √√√ with a key to represent degrees of colour/cloudiness or a number scale 1 to 5 for intensity of colour with a key.

7.2.3 PDO – Presentation of Data and Observations:

PDO recording – within a given investigation, the procedure should allow candidates to learn to

(a) Record quantitative results and qualitative observations in a table.

Tables should have clearly ruled cells with no units in the body of the table.

(i) Quantitative results:

- heading for independent variable in left column or top row with appropriate units
- heading for dependent variable with units
- record to same level of precision dependent on the measuring instrument used, e.g. using a mm scale should record in mm not cm and to 0.5 mm. All readings should be to the same level of precision, for example if measured in whole mm then all readings to whole mm. More information **www.rsc.org/images/RSCmeasurements_teacher_tcm18-189111.pdf**

(ii) Qualitative observations:

- heading for independent variable, for example solutions or samples
- heading for dependent variable, for example observation of colour.

(b) Record calculated values (processed results) and deductions in a table (with raw results

Select, if appropriate:

- to include processed results in the table with the raw results, e.g. mean of repeated or replicated results
- to include a separate table to show independent variable with processed results, e.g. concentration with rate.

PDO display within a given investigation or from given data allow candidates to learn to

(c) Display calculations showing all the steps in the calculation (the answer is not always important)

Calculate using raw results or given data, showing all the steps in the calculation:

(i) mean

(ii) percentage

(iii) change in mass or length

(iv) percentage change, gain or loss

(v) rate of reaction.

(d) Use the correct number of significant figures for calculated quantities.

Calculated quantities should be given to the same number of significant figures as the measured quantity that has the smallest number of significant figures. For example, if time is measured to 1 significant figure and volume to 2 significant figures, then the calculated rate should be to 1 significant figure, not 2 or more.

Centres can find more information about significant figures at **www.rsc.org/images/RSCmeasurements_teacher_tcm18-189111.pdf**

PDO layout within a given investigation the procedure should allow candidates to learn to:

(i) Select whether data should be shown as a graph or chart and present clearly and accurately.

Graphs or charts should be drawn with:

- *Orientation*: independent variable on the *x*-axis, clearly labelled (as from the table heading) with units where appropriate and dependent variable (as from the table heading) on the *y*-axis labelled with units, where appropriate
- *Scales*: both axes should use most of a grid and allow the graph to be read easily to half a 2 mm square, such as 1, 2, or 5 units to a 20 mm
- *Plot* all points or bars accurately. Points should be drawn with a sharp pencil, but must be visible, a cross (drawn with two lines less than 2 mm in length each) or a small (no more than 1 mm diameter) dot in a circle should be used and the intersection of the cross or centre of the dot must be exactly at the required point
- *Bars* should be drawn exactly along the horizontal lines with a fine ruled line
- *Line* – follow the Institute of Biology guidelines – decide based on data provided whether a straight line or line of best fit; or smooth curve or if there is not enough data then join the points with ruled straight lines. Do not extrapolate the graph unless this can be assumed from the data. Lines should be clear, sharp and unbroken (about 0.5 mm thick)
- *Chart* – consider whether the bars should be separate (for non-quantitative data on *x*-axis) or joined (for quantitative, e.g. heights or lengths on *x*-axis). Lines should be clear, sharp and unbroken (about 0.5 mm thick) and bars unshaded.

7.2.4 ACE Analysis, conclusions and evaluation

ACE Analysis (interpretation of data or observations)

Within a given investigation the procedure should allow candidates to learn to:

(a) Calculate correctly other quantities from data or a graph.

Calculate correctly using quantitative results or provided data, to include:

- mean
- percentage
- change in mass or length
- percentage change, gain or loss
- rate of reaction using results or using the gradient of a line graph.

(b) Find an unknown value by using co-ordinates or axis intercepts on a graph or qualitative results for identification of known solutions:

- unknown concentrations where a calibration curve has been drawn
- values for 50% plasmolysis
- zero changes in mass in osmosis investigations
- rate of enzyme reaction from time as 1/time = s^{-1} or from gradient of a line
- estimate unknown concentrations from results for known concentrations
- identify unknown solutions using biological molecule tests.

(c) Identify anomalous results.

Check for anomalous results and remove any anomalous readings when calculating, for example, means.

(d) Describe the patterns and trends shown by tables and graphs.

Overall trends should be described and data quoted when a change occurs.

ACE conclusions

Within a given investigation, the procedure should allow candidates to learn to:

(e) draw conclusions

- from the patterns and trends in data
- on whether experimental data supports a given hypothesis
- from results, including estimating an unknown concentration from known concentrations

(f) make scientific explanations, using skills, knowledge and understanding of the AS Biology syllabus, of

- data
- observations
- calculated values
- described conclusions
- information provided in unfamiliar contexts.

ACE Evaluation

Within a given investigation, the procedure should allow candidates to learn to:

(g) Identify the significant sources of error in a particular investigation.

Any variable that makes the results less accurate or reliable and that may change during the recording of results.

For a range of investigations, consider carefully, for example, whether evaporation or temperature are likely to vary significantly during the time that results are recorded.

Note: Contamination is not considered a significant source of error – washing correctly should remove contamination.

(h) Estimate quantitatively, by calculating the actual error, to evaluate the uncertainty in quantitative measurements and evaluate the confidence in the accuracy of resuts (how close they are to the true value).

Actual error is taken to be half the value of the smallest division on the apparatus used, then consider whether the measurement involves uncertainty at each end.

For example, actual error of:

- a thermometer – where the smallest division is 0.2°C then the start temperature has an uncertainty of half 0.2 = 0.1°C and the next reading also has an uncertainty of 0.1°C, so an actual error of +/– 0.2°C.
- a syringe – as long as the volume is all released then there is only one uncertainty – so if the smallest division on the syringe is 0.2 cm^3, then the uncertainty is 0.2/2 = +/– 0.1 cm^3.

Where a particular measurement is given, then a percentage error can be calculated using the uncertainty above.

For example:

- if the temperature rise is 15°C and the uncertainty is 0.2°C, then the percentage error is $0.2/15 \times 100 = 1.3\%$
- if the volume measured in the syringe is 0.8 cm^3, then the percentage error is $0.1/0.8 \times 100 = 13\%$.

Candidates should be used to looking at experiments and assessing the relative importance of errors in measurement or in making observations so that they can judge which sources of error are most important. Candidates should be familiar with simple means of estimating error, such as the errors built in to measuring devices (see **www.chemistry-react.org/go/Tutorial/Tutorial_4428.html**) or in the observer's ability to observe, or in experiments where the method's limitations introduce errors (such as heat loss when trying to assess the energy content of biological materials). They should be able to express these errors in standard forms (such as length = 73 mm ± 1 mm, or temperature increase = 14 °C ± 4 °C).

(i) Evaluate the effectiveness of the standardisation of variables and thus the confidence with which conclusions might be drawn.

Consider whether the standardised variables had an effect on the general trend or pattern and therefore the confidence in the conclusion.

ACE Evaluation

Within a given investigation, the procedure should allow candidates to learn to suggest improvements to the procedure or modifications to the investigation or extend the investigation.

Consider systematic or random errors.

Systematic errors, for example a thermometer which reads 1 °C higher than the actual temperature.

Random errors may be due to variability of biological material or random variations in the temperature of a room.

(j) Suggest modifications to a procedure that will increase the accuracy of the experiment or accuracy of the observations that can be made, including use of alternative methods or strategies to investigate the question.

Suggestions to include, how to:

- standardise relevant variables
- use a measurement method which is more accurate and reliable
- collect more data by repeats or replicates to obtain a mean.

(k) Suggest ways in which to extend the investigation to answer a new question and describe such modifications clearly in words or diagrams.

Suggestions to include, how to:

- change a different independent variable
- standardise all other variables
- use an accurate and reliable method to measure the dependent variable.

7.2.5 Development of skills used in studying organisms involving microscopy:

- Manipulation, measurement and observation – decisions on how to use the light microscope, make and stain slides of specimens, calibrate and use an eyepiece graticule and collection of observations and measurements of specimens
- Presentation of observations – recording detailed observations of specimens on microscope slides; display of calculations with reasoning using measurements from eyepiece graticule and photomicrographs and data layout (plan diagrams and drawings)
- Analysis, conclusions and evaluation – analysis of measurements and comparison of observations; drawing conclusions and evaluation of measurements

MMO Manipulation (use of experimental techniques), Measurements and Observations

MMO decisions

Using a light microscope:

(a) Decide how to set up a light microscope to view and observe specimens, in order to make plan diagrams to show tissue distribution and in order to show details of cells.

To include how:

- to adjust the light
- to find the specimen using low power (x10) objective lens as wider field of view, to focus by having objective lens close to slide (not looking through the microscope) then turning lens away from slide
- to position specimen in centre of field of view
- to change objective lens to higher power (x40) to reduce field of view and increase magnification and use fine adjustment to focus lens away from slide.

Decide on:

- an appropriate objective lens
- light level – reducing light to view more transparent specimens by closing iris.

(b) Identify named tissues in plant and animal specimens.

Decide on:

- regions of tissues present in a specimen
- labels.

(c) Decide how to stain and make a slide of a specimen.

Decide how to:

- obtain the tissue or cells
- mount onto a glass/microscope slide and add an appropriate stain
- lower a coverslip onto the specimen
- remove excess stain/liquid.

(d) Decide how to calibrate an eyepiece graticule using a stage micrometer.

Use a stage micrometer and decide where eyepiece graticule scale lines up with stage micrometer scale.

(e) Decide how to obtain actual sizes of tissues or cells using eyepiece graticule.

Use and decide:

- the appropriate objective lens to measure tissues or cells
- the correct units for calculating sizes using light microscope
- how many measurements to take to obtain a mean.

(f) Decide how to count cells or cell organelles.

- use samples from the whole slide or field of view
- use a grid/haemocytometer.

MMO collection

Using a light microscope and prepared slides and photomicrographs:

(g) Collect observations, by drawing plans, of the distribution of tissues in a specimen.

- plan diagrams of whole specimen or part of a specimen to show the distribution of tissues ,with no cells drawn and correct proportions of tissues, using the (uncalibrated) eyepiece graticule scale.

(h) Collect observations by drawing the observable features of tissues or cells in a specimen.

Drawings must have the:

- correct proportions, for example of layers in a plan diagram or dimensions of cells or thicknesses of cell walls
- correct cells in detail, with correct shapes, relative sizes and thicknesses of cell walls where appropriate (using (uncalibrated) eyepiece graticule scale)
- plant cell walls are drawn with two lines with a middle lamella between adjacent cells
- only observable features are recorded, for example appropriate cell contents.

(i) Collects correct number of eyepiece graticule divisions to stage micrometer divisions and measures accurately tissues or cells.

(j) Collects correct observations from specimens.

To include:

- numbers of cells or cell organelles using sampling or a grid or tally counts
- stained to non-stained cells
- similarities and differences between two specimens.

7.2.6 PDO Presentation of data and observations

PDO recording

(a) Record fine details of the specimen.

To include:

- drawing of detailed shapes of layers or outlines of specimens in plan diagrams
- drawing of the shape and position of observable cell organelles in cells.

PDO display

(b) Display calculations.

Calculate, showing all the steps in finding:

- the calibration of the eyepiece graticule
- actual size using
  - eyepiece graticule
  - magnification
  - scale bar
- magnification
- number, e.g. stomata per unit of area, e.g. field of view
- a mean measurement of length or number
- find a ratio which is expressed as larger whole number to smaller whole number, to the lowest common denominator, for example if figures are 24 to 12 then should be taken to 2 : 1 but if 35 to 15 then only rounds down to 7 : 3.

(c) Use the correct number of significant figures for calculated quantities.

Calculated quantities should be given to the same number of significant figures as the measured quantity that has the smallest number of significant figures. For example, if a line is measured using a mm ruler then the measurement should be to 0.5 mm.
Magnification should be a whole number only.

PDO layout

(d) Make drawings using a sharp pencil to give finely drawn lines with no kinks or breaks.

Drawings should:

- have clear, sharp, unbroken lines
- be unshaded
- use most of the available space to show all the features observed in the specimen.

(e) Organise comparative observations of specimens of biological material.

feature	specimen X	specimen Y
	similarities	

Organisation for two specimens should have a table with three columns:

- the first column headed feature
- second and third column with the two specimens
- Similarities should have a clear heading across columns two and three and the cells merged below the heading.

7.2.7 ACE Analysis, conclusions and evaluation

ACE Analysis (interpretation of data or observations)

(a) Calculate correctly other quantities from data.

Calculate:

- the calibration of the eyepiece graticule scale
- actual size of a specimen, using
  - a calibrated eyepiece graticule
  - a magnification
  - a scale bar
- the magnification of a specimen
- the number in a field of view, e.g. number of stomata per unit of area.

(b) Compare observable features of specimens of biological material.

Similarities and differences should be observed and recorded, for example between microscopic slides of specimens and photomicrographs of microscopic specimens.

ACE conclusions

(c) Make scientific explanations of the observations or calculated values, using the skills, knowledge and understanding acquired from the AS Biology syllabus:

- observations of specimens
- calculated values
- how a specimen is adapted for a particular function or to survive in a particular habitat.

ACE evaluation

(d) Estimate quantitatively the uncertainty in quantitative measurements.

Actual error is taken to be half the value of the smallest division on the apparatus used, then consider whether the measurement involves uncertainty at each end of a scale.

For example – actual error of a mm ruler (where 0 is not at the end) will have an uncertainty at 0 end of 0.5 mm and an uncertainty where the measurement is taken of 0.5 mm so the total uncertainty is 0.5 + 0.5 = 1.0 mm and for each measurement the actual error is +/– 1.0 mm

Where a particular measurement is given then a percentage error can be calculated using the uncertainty above.

For example

- if the length measured is 6 mm and the actual error is +/– 1.0 mm then the percentage error is $1.0 \div 6.0 \times 100 = 17\%$.

7.2.8 Administration of the practical test

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

A document called the *Confidential Instructions* will be despatched to Centres, several weeks before the date of the examination. The *Confidential Instructions* will detail the apparatus that will be required and how it should be provided for candidates. Centres should contact the Despatch Department at Cambridge if they believe the *Confidential Instructions* have not been received.

Access to the question paper itself is not permitted in advance of the examination.

It is essential that absolute confidentiality be maintained in advance of the examination date: the contents of the *Confidential Instructions* must not be revealed either directly or indirectly to candidates.

The *Confidential Instructions* contain a Supervisor's Report Form. Centres must complete this form and enclose a copy in each envelope of scripts. A sample set of results may also be helpful to the examiners, especially if there was any local difficulty with apparatus. A missing report can delay the marking process.

If there is any doubt about the interpretation of the *Confidential Instructions* document or the suitability of the apparatus available, enquiries should be sent to the Product Manager for Biology at Cambridge, using either e-mail (**info@cie.org.uk**) or fax (+44 1223 553558) or telephone (+44 1223 553554).

8.2.9 Apparatus required for Paper 3 (Advanced Practical Skills 1/2)

The apparatus required for Paper 3 (Advanced Practical Skills 1/2) will vary from paper to paper. The Confidential Instructions will include a complete list of apparatus and materials required for each question. Centres should follow the Confidential Instructions very carefully.

To give some variety in the questions set, the examiners may require unusual items or equipment. The list of practical apparatus and materials in Section 7.2 gives details of the items that are most frequently required. Candidates should be familiar with using these.

Microscopes provided for candidates' use in Paper 3 must be fitted with:

- Eyepiece lens, ×10 (equal to 16 mm or $\frac{2}{3}$")
- Low-power objective lens, ×10 (equal to 16 mm or $\frac{2}{3}$")
- High-power objective lens, ×40 (equal to 4 mm or $\frac{1}{6}$")
- Eyepiece graticule fitted within the eyepiece and visible in focus at the same time as the specimen.

To avoid confusion, Cambridge request that only the lenses specified above are fitted in the microscopes to be used in the examination. Any lenses which are not ×10 or ×40 should be removed or replaced.

7.3 Paper 5

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

- planning;
- analysis and evaluation.

This exam paper does not need laboratory facilities. However, **Centres should note that candidates cannot be prepared properly for this paper without carrying out a large amount of laboratory work during their course of study.** In particular, candidates can only learn how to plan experiments effectively if they are required, on many occasions:

- to plan an experiment;
- to carry out the experiment according to their plan;
- to evaluate what they have done.

Centres must allow for many hours of laboratory-based work, and must make sure that teachers give careful supervision to make sure that candidates carry out experiments with due regard to safety. It is assumed that candidates have developed skills as part of the AS course and are able to use those in more complex investigations and to interpret data in a variety of ways.

The paper has two or more questions with a total of 30 marks available. Candidates must design an experimental investigation for a given problem. Candidates may be asked to answer using extended, structured writing, and use appropriate diagrams and tables as illustrations. Candidates may have to express a prediction as a written hypothesis linking independent and dependent variables, or as a graph showing the expected result. Some activities require the candidate to make analyses, evaluations and conclusions. For these questions, the candidates are given some experimental data and candidates may be asked to decide for themselves how to analyse and evaluate the data, and what conclusions to make.

The examiners may set some questions on this paper that cannot easily be investigated experimentally in school laboratories, either because of the cost of equipment (such as colorimeters or large fermenters) or because of the samples and materials not being easily available (such as living individuals of rare species, or radioactive materials to be used as markers). All questions can be answered using theory and equipment from the AS and A2 syllabus. The examination paper provides any information that candidates are not expected to know about theory or equipment, if the candidates need this information to answer the question. The amount of information included in a question is sufficient for the candidates have enough time to read and consider that information.

7.3.1 Mark scheme for Paper 5

Paper 5 is marked using the mark scheme shown in the table. The sections following the table list the expectations for each mark category.

Skill	Total marks	Breakdown of marks	
Planning	15 marks	Defining the problem	5 marks
		Methods	10 marks
Analysis, conclusions and evaluation	15 marks	Dealing with data	8 marks
		Evaluation	4 marks
		Conclusion	3 marks

7.3.2 Planning

Defining the problem

Candidates are provided with a scenario and background information to give the context within which they must define the problem. They should be able to use this information to work out the key variables in the investigation.

Candidates should be able to:

- Express the aim of the experiment or investigation as a prediction or hypothesis. This should be a quantitative, testable, falsifiable prediction of the likely outcome, based on the information given in the question and on their knowledge and understanding of the topic being considered. The hypothesis may be expressed in words or in the form of a sketch graph showing the expected result.
- Identify the independent variable in the experiment or investigation as the factor(s) that is manipulated or changed. An experiment may incorporate changes in two independent variables, e.g. the effect of light intensity at two or more concentrations of carbon dioxide on photosynthesis.
- Identify the dependent variable as the factor that is **measured directly** during the experiment or investigation. The dependent variable responds to the changes in the independent variable. In some cases there may be more than one dependent variable measured in an experiment, e.g. both the carbon dioxide release and oxygen uptake may be measured in respiration experiments. In some investigations, the hypothesis or aim may be stated in terms of a variable that cannot be measured directly, e.g. rate of transpiration. To find the rate, a **measurable** aspect of transpiration is used, such as mass loss, distance moved by water in a capillary in a specified time.
- Identify which variables must be standardised. They must give a list of key variables to control in order to test the hypothesis effectively. They should only include variables that are likely to have some effect on the material involved (e.g. concentration of test solutions), but not those likely to have a very small effect (e.g. using the same test-tube).

Methods

The candidate should produce a method where they could collect the necessary data without difficulty if the apparatus were used as described. Candidates should be able to:

- describe the method they would use to vary the independent variable, and the ways in which they would make sure that they had measured its values accurately;
- describe how they would measure the dependent variable. The measuring instruments chosen should measure the correct quantity to a suitable precision. This may include the use of monitoring devices and computer technology to record changes;
- describe how they would standardise each of the other key variables. The methods chosen should be suitable to the apparatus being used and the nature of the investigation, e.g. a thermostatically controlled water bath is not suited to maintaining the temperature of bacteria growing on Petri dishes;
- explain how they would use any control experiments to make sure that it is the independent variable that is affecting the dependent variable and not some other factor. Control experiments can be of the type where all factors are identical to the experimental treatment except that the value of the independent variable is zero, e.g. water is used instead of a test solution, or they may be of the type used to confirm that, for example, it is an organism that is causing a particular effect, by leaving out or replacing the organism by non-living material, e.g. sterile glass beads instead of an insect in a respirometer;
- describe how to use apparatus and the steps that they would use in the procedure. Candidates should use words and labelled diagrams for describing the apparatus and how to use it;
- suggest appropriate volumes and concentrations of reagents, and explain how different concentrations would be prepared.
  Candidates should be able to explain how to make up solutions:
  - in % (w/v), for example by adding a known mass of solute to a small volume of solvent, mixing until fully dissolved and then making up to the final volume with solvent;
  - in mol dm^{-3}, by dissolving the molar mass of solute and then making up to 1 dm^3 with solvent;
- by using serial dilution, by making the same dilution step over and over, using the previous dilution as the input to the next dilution in each step. Since the **dilution-factor is the same in each step**, the dilutions are a geometric series, i.e. a constant ratio between any adjacent dilutions, e.g. a stock solution of a known concentration is made and 1 cm^3 is added to 9 cm^3 of solvent (usually water), making a 10^{-1} or, 10× dilution, or 1 in 10, or 10 fold. For the next dilution, 1 cm^3 of the 10^{-1} solution is removed and added to 9 cm^3 of solvent; making a 10^{-2} or, ×100 dilution or, 1 in 100 or, 100 fold dilution. The process of removing 1 cm^3 of a solution and adding to 9 cm^3 of solvent to make a dilution is continued until the required number of dilutions is obtained;
- using proportional dilution, by adding a unit volume of a solution of a known concentration to a solvent to obtain the required concentration, e.g. to dilute a stock solution by 5, 1 cm^3 of the stock solution is added to 4 cm^3 of solvent. This gives a 1:5 dilution. To make a standard volume of a specific concentration a formula $V_1C_1 = V_2C_2$ can be used. V_1 is the volume of the stock solution, C_1 the concentration of the stock solution and V_2 is the volume of the required solution, C_2 is the concentration of the required solution, e.g. a stock solution contains 100 mg cm^{-3} (C_1) and need to make 10 cm^3 (V_2) of a solution with a concentration of 25 mg cm^{-3} (C_2). The volume of stock solution needed is V_1 = 10 cm^3 (V_2) × 25 mg cm^{-3} (C_2) / 100 mg cm^{-3} (C_1). Cancelling units, V_1 = 100 cm^3 (V_2) × 25 (C_2) / 100 (C_1) = 2.5 cm^3;
- describe how they would ensure the reliability of results by considering any anomalous results and the spread of results by inspection and by using standard deviation, standard error or 95% confidence limits. Results are reliable if they are repeatable by the same student and reproducible by others;
- describe how they would ensure the validity of the results by considering both the reliability and the success at measuring the intended dependent variable;

- assess the risks of their proposed methods. Candidates should be able to carry out a simple risk assessment of their plan, identifying the areas where an accident or injury is most likely to happen and the areas where it would be most serious;
- describe precautions that they would take to keep risks as low as possible. They should be able to suggest appropriate safety precautions specifically related to the risks that they have identified. For example, they might point out that soda lime used to absorb carbon dioxide is corrosive and poses a particular risk if they come in contact to the skin and cornea. Wearing gloves and eye protection would therefore be an appropriate precaution.

7.3.3 Analysis, conclusions and evaluation

Dealing with data

Candidates should be able to:

- work out which calculations are necessary for making conclusions from provided data, including those designed to assess error levels, confidence limits, statistical tests and means of presentation of data;
- use calculations to simplify or explain data;
- use appropriate statistical tests to assess the variability of data or the statistical differences between samples;
- use tables and graphs to point out the key points in quantitative data, including the variability of data.

Candidates should know how to choose and carry out calculations needed for simplifying data and making it comparable. These calculations may include the mean, median, mode, percentage and percentage gain or loss.

Candidates should be able to sketch or draw suitable graphs displaying the independent variable on the *x*-axis and the dependent variable on the *y*-axis, and satisfying the criteria laid out in Paper 3 (Section 6). In addition, they should include confidence limit error bars, calculated using standard error.

Candidates should know how to choose and carry out the key steps of statistical methods designed to assess variability in data including

- range
- inter-quartile range
- standard deviation
- standard error.

Candidates should be able to choose and use (when given suitable equations) statistical tests designed to find the differences between samples:

- chi squared test
- standard error
- *t*-test.

Candidates should be able to give reasons for a choice of statistical test in relation to the type of data collected and be able to state a null hypothesis for a statistical test. It is expected that candidates can use figures with standard deviation or standard error, or graphs with standard error bars, to determine whether differences in mean values are likely to be statistically significant. Candidates should also be able to calculate the degrees of freedom for a statistical test and use a probability table to determine the significance of a calculated value for the *t*-test and the chi-squared test.

Candidates should be able to:

- distinguish between different types of variable and the different types of data they collect;

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, gender
ordered	ordinal, i.e. values that can be placed in an order or rank, 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	interval, that can have any value within a specific range that can be a whole number, fraction or a decimal. It can be counted, ordered and measured, e.g. body mass, leaf length
discrete	interval, that can have only a limited number of values that is a whole number, e.g. the number of seeds in a bean pod, number of yeast cells in a haemocytometer grid

Further **Notes on the use of statistics in biology** can be found in Section 7.4.

Evaluation

Candidates should be able to:

- identify anomalous values in provided data and suggest how to deal with such anomalies. In a table or graph of data, candidates should be able to identify values that are clearly anomalous, and suggest strategies for dealing with such anomalies, including repeating the experiment until consistent results are obtained or leaving out the affected data;
- within familiar contexts, suggest possible explanations for anomalous readings. Where investigations use familiar contexts, which the candidates have explored during the course (those marked **[PA]** in the syllabus content), candidates can be asked to suggest possible causes for such anomalies (above and beyond 'investigator error'), e.g. answers taken from their own experience of problems built in to the particular investigation;
- assess whether the provided readings have been replicated sufficiently, and describe the adequacy of the range of data given. Candidates must know why replicating data is important and the practical limits on replication. Candidates must be able to show instances where the investigator should have taken readings at lower or higher values of the independent variable in order to give a complete range of values. They must also be able to point out situations where there are gaps in the range that reduce the information that the investigation can give, e.g. around a key turning point. Candidates should be able to assess whether the method of measuring is appropriate for the dependent variable, e.g. using a pH meter is more likely to give more accurate and reliable results than using an indicator and a colour chart to measure changes in pH;
- use the information given to assess whether selected variables have been controlled effectively. Candidates may be given information that will help them to assess the extent to which a particular

variable has been effectively controlled (e.g. the temperature recorded within each of a number of samples in which it is supposed to be the same);

- use these evaluations and the information given to make informed judgements about how much confidence can be put in any conclusions. Candidates should be able to bring all this information together and so to make informed judgements about the validity of the investigation and how much it can be trusted for testing the hypothesis.

Conclusions

Candidates should be able to:

- draw conclusions from an investigation, giving a detailed description of the key features of the data and analyses, and considering whether experimental data supports a given hypothesis. The candidates should give key points of the raw data, processed data, graphical representations of it and statistical test results, including quoting relevant figures. They should clearly show the strength or weakness of any support for or against the hypothesis. In particular, they should be able to show whether the hypothesis has been fully supported or not supported by the data;
- give detailed scientific explanations of the data and of their conclusions, using the skill, knowledge and understanding that they have gained from their studies of the AS and A2 syllabus. The conclusions should include detailed scientific explanations and these should play an important part in this higher-order practical skill assessment. The candidates must refer to knowledge and understanding gained in the theory part of the course to give explanations of their practical conclusions. For example, candidates should make reference to the rate of effective collisions between enzyme molecules and substrates to explain the conclusions made about an enzyme-related hypothesis;
- make further predictions, ask informed and relevant questions and suggest improvements. Where appropriate, candidates should have the chance to ask questions based on their conclusions and so to derive further predictions and hypotheses. Within familiar contexts and in relation to the evaluations they have made, candidates may have the chance to suggest how the investigation could be improved to increase the confidence in drawing conclusions.

8. Appendix

8.1 Safety in the laboratory

Centres are responsible for safety matters. The following UK associations, websites, publications and regulations may be helpful.

Associations

CLEAPSS is an advisory service, which provides support in science and technology for a number of local authorities and their schools, including schools for pupils with special needs. International schools, post-16 colleges, teacher-training establishments, curriculum developers and others can apply for associate membership: see **www.cleapss.org.uk/secmbfr.htm**

Websites

www.ncbe.reading.ac.uk/NCBE/SAFETY/menu.html
www.microbiologyonline.org.uk/safety.html

Publications

ASE (2006) *Safeguards in the School Laboratory*, 11th edition
ASE (2001) *Topics in Safety*, 3rd edition
CLEAPSS (updated 2005) *Laboratory Handbook* (only available to CLEAPSS members)
CLEAPSS (2005 update of 1995 edition) *Hazcards* (only available to CLEAPSS members)
DfES (1996) *Safety in Science Education* (HMSO)
SSERC (1997) *Hazardous Chemicals Manual*
SSERC (2002) *Hazardous Chemicals: An Interactive Manual for Science Education* (CD)

UK Regulations

Control of Substances Hazardous to Health Regulations (COSHH) 2002, available at **www.opsi.gov.uk/SI/si2002/20022677.htm**

A brief guide can be found at **www.hse.gov.uk/pubns/indg136.pdf**

Resources are also listed on Cambridge's public website at **www.cie.org.uk**. Please visit this site on a regular basis as the Resource lists are updated through the year.

Access to teachers' email discussion groups, suggested schemes of work and regularly updated resource lists may be found on the Cambridge Teacher Support website at **http://teachers.cie.org.uk**. This website is available to teachers at registered Cambridge Centres.

8.2 Laboratory equipment

This is a list of basic materials and apparatus that a well-equipped biology laboratory would contain. Many of these items are regularly used in the practical test. The list is *not* exhaustive. Other items may be required to allow for variety in the questions set.

In accordance with the COSHH (Control of Substances Hazardous to Health) Regulations, operative in the UK, a hazard appraisal of the list has been carried out.

The following codes have been used where relevant.

C = corrosive substance
F = highly flammable substance
H = harmful or irritating substance
O = oxidising substance
T = toxic substance

General:

- Test-tubes and large test-tubes (boiling tubes) – some test-tubes should be heat resistant
- Test-tube holders or similar means of holding tubes
- Test-tube racks or similar places in which to stand tubes
- Bungs to fit test-tubes/boiling tubes
- Bungs with delivery tube to fit test-tubes/boiling tubes
- Specimen tubes with corks
- A means of heating – Bunsen burners or similar (candidates should be familiar with setting up and maintaining a water bath)
- Thermometers
- Measuring cylinders
- Means of measuring small volumes, such as syringes (various sizes)
- Plastic tubing or rubber tubing to fit syringes
- Teat pipettes (plastic or glass)
- Beakers (various sizes)
- Tripod stands and gauzes
- Filter funnels and filter paper
- Petri dishes (plastic) or shallow containers to hold small volumes (e.g. 20 cm^3)
- White tiles or other suitable surfaces on which to cut
- Spotting tile or similar with space for 12 separate drops
- Glass slides and coverslips
- Conical flasks
- Clamp (retort) stands and bosses
- Visking (dialysis) tubing or suitable alternative
- Capillary tubing
- Soda glass tubing
- Paper towelling or tissue
- Cotton wool
- Solid glass rods
- Spatulas
- Black paper/aluminium foil

- Means of writing on glassware (water-resistant markers)
- Hand lenses (not less than x6, preferably x8)
- Forceps
- Scissors
- Mounted needles
- Cutting implement, such as solid-edged razor blade/knife/scalpel
- Rulers in mm (ideally clear plastic)
- Mortars and pestles
- Safety spectacles or other suitable eye protection
- Microscope and lamp/inbuilt illumination with high-power and low-power objective lenses (1 each or 1 between 2) *see also section 6 for specifications*
- Eyepiece graticules and stage micrometer scales
- Microscope slides and glass coverslips
- Haemocytometers
- Bench lamp with flexible arm
- Balance (to 0.1 g)
- Water baths (thermostatically controlled) or means to supply hot water
- Cork borers
- Stopclock/timer showing seconds
- Simple respirometer – can be 'homemade'
- Pipe cleaners/other suitable aid to demonstrate mitosis and meiosis
- Culture bottles, autoclave
- Inoculating loops/wires
- Tape for sealing dishes
- Cultures of live yoghurt
- Appropriate cultures of microorganisms, such as *Escherichia coli, Bacillus subtilis*

Stocks of:

- [**H**] – Iodine in potassium iodide solution
- [**H**] – Benedict's solution
- [**C**] – Biuret reagent/potassium hydroxide and copper sulfate solution
- [**F**] – Ethanol (for fats test)
- [**F**] – Methylated spirit (for extraction of chlorophyll)
- Sucrose (use Analar (AR) for non-reducing sugar test. Some types of table sugar do not contain glucose.)
- Glucose
- Starch
- Albumen (or egg white)
- [**C**] – Potassium hydroxide
- [**C**] – Sodium hydroxide
- Sodium chloride
- [**H**] – Dilute hydrochloric acid
- Hydrogen carbonate indicator (with air pump to equilibrate to atmospheric carbon dioxide)
- Sodium bicarbonate/sodium hydrogen carbonate
- [**H**] – Limewater
- [**H**] – Hydrogen peroxide
- Distilled/deionised water
- Universal Indicator paper and chart
- Litmus paper
- Eosin/red ink
- [**H**] – Methylene blue
- Vaseline/petroleum jelly (or similar)
- DCPIP (dichlorophenol-indophenol)
- Ascorbic acid (vitamin C)
- Drastix/Clinistix for testing glucose concentration
- [**H**] – Enzymes: amylase, trypsin (or bacterial protease)
- Materials for preparing immobilised enzymes: calcium chloride, sodium alginate
- Plant sources of catalase, e.g. sweet potatoes, mung beans, potatoes
- Wheat, barley or similar as a source of starch
- Non-competitive enzyme inhibitor (e.g. [**H**] – copper sulfate – hydrated)
- Stains for preparing slides to show mitosis – e.g. acetic carmine
- [**H**] – Feulgen stain (Schiff's reagent)
- Apparatus/chemicals for water cultures to show effect of Mg and N on growth
- Nutrient broth, nutrient agar and technical agar (not nutrient)
- Appropriate disinfectants

Apparatus for sampling animals:

- Beating tray ('homemade')
- Pooter ('homemade')
- Sweeping net (muslin)
- Plankton net and dip net (if aquatic environment is being sampled)
- Pitfall trap/jam jar; suitable cover to prevent water entry
- Trays for hand sorting

Slides of:

For Cambridge International AS Level

- Mitosis
- TS stem, TS root and TS leaf of, for example, dicotyledonous mesophyte (such as *Ligustrum* or *Prunus* or local equivalent), maize, rice, sorghum, wheat, xerophyte leaves
- LS stem, LS root to show xylem vessel elements and sieve tube elements and companion cells
- TS trachea, TS bronchus, TS bronchioles
- TS lungs to show alveoli
- TS artery, TS vein
- Blood smear
- Animal and plant cells; Protoctists (e.g. *Amoeba*, *Euglena* or local equivalents, for example from a culture made with water and hay to stimulate single cell organisms)

For Cambridge International A Level

- Meiosis
- TS anther, TS ovule
- Pollen
- Stamen and stigma of wind-pollinated and insect-pollinated plants
- VS maize fruit
- TS pancreas
- TS kidney
- TS spinal cord
- TS ovary, TS testis
- Examples of organisms representing the three kingdoms; Protoctista (e.g. *Amoeba*, *Euglena* or locally available equivalents); Prokaryotae (e.g. bacterial smear, cyanobacteria); Fungi (e.g. yeast, *Penicillium*)

8.3 Mathematical requirements

At AS, candidates should be able to:

- recognise and use expressions in decimal and standard form
- use a calculator for addition, subtraction, multiplication and division, and for finding the arithmetical mean and to find and use x^2, $\frac{1}{x}$, $\sqrt{x}$, $\log_{10}x$
- take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is appropriate for the question
- make estimations of the results of calculations (without using a calculator)
- recognise and use ratios
- calculate percentages correctly, express changes or errors as percentages, and express percentages as changes or errors
- understand and use the symbols $<$, $>$, Δ, $\approx$, /, $\propto$, Σ
- calculate the areas of right-angled and isosceles triangles, the circumference and area of circles, the areas and volumes of rectangular blocks and cylinders
- translate information between graphical, numerical and algebraic forms
- construct and interpret frequency tables and diagrams, pie charts and histograms
- choose appropriate variables and scales for graph plotting, using standard 2mm-square graph paper
- for linear graphs, calculate the rate of change
- recognise when it is appropriate to join points on a graph with straight rules lines and when it is appropriate to use a line of best fit
- choose, by inspection, a straight line that will serve as the best straight line through a set of data points presented graphically
- understand, draw and use the slope of a tangent to a curve as a way to obtain the rate of change
- understand and use the prefixes giga (G), mega (M), kilo (k), micro (μ) and nano (n).

At A2, candidates should also be able to:

- understand probability well enough to understand genetic ratios
- understand the principles of sampling as they apply to biological situations and data
- understand the importance of chance when interpreting data
- use simple statistical tests such as χ^2 test and *t*-test.

8.4 Notes on the use of statistics in biology (Cambridge International A Level only)

Candidates should know how to apply a *t*-test, chi-squared test, standard deviation and standard error. In biology, *t*-tests are valuable for testing for the significance of differences between samples. The chi-squared test allows the results of breeding experiments and ecological sampling to be assessed. Standard deviation is useful for expressing the variation from the mean. Standard error is useful for expressing how reliable an estimate of the mean is, and for putting error bars on graphs. Details of each of these tests can be found in many books on statistics for biology.

Candidates are **not** expected to remember the following equations and symbols. They **are** expected to be able to use the equations to calculate standard deviations, to put error bars on graphs, to test for significant differences between the means of two small unpaired samples and to perform a chi-squared test on suitable data from genetics or ecology. Candidates will have access to the equations, the meanings of the symbols, a *t*-table and a chi-squared table.

standard deviation $$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$$

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

χ^2 test $$\chi^2 = \sum \frac{(O-E)^2}{E} \qquad v = c - 1$$

standard error $$S_M = \frac{s}{\sqrt{n}}$$

Key to symbols

s = standard deviation	$\bar{x}$ = mean S_M = standard error	c = number of classes
Σ = 'sum of'	n = sample size (number of observations)	O = observed 'value'
x = observation	v = degrees of freedom	E = expected 'value'

Candidates should note that, on some calculators, the symbol σ may appear instead of the symbol s.

Candidates are not expected to understand the difference between $s_n(\sigma_n)$ and $s_{n-1}(\sigma_{n-1})$. χ^2 tests will only be expected on one row of data. Candidates should have a basic understanding of what is meant by the term *normal distribution* and should understand levels of significance. (Tables will be provided.)

Papers 4 and 5 may include questions involving the use of standard deviation, standard error, a *t*-test or a χ^2 test. Candidates will **not** be expected to carry out all of the steps in these calculations during an exam, but they may be given partly completed calculations to finish.

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

8.5 Glossary of terms

Cambridge hopes that the glossary (which is relevant only to Biology) will be helpful to candidates as a guide, although it does not cover every command word that might be used in Biology exams. We have deliberately kept the glossary brief, both in numbers of terms included and also in the descriptions of their meanings. Candidates should be aware that the meaning of a term must depend, in part, on its context.

1. *Define* (the term(s)…): only a formal statement or equivalent paraphrase is required.
2. *What do you understand by/What is meant by* (the term(s)…): a definition should be given, together with relevant comment on the significance or context of the term(s), especially where two or more terms are included in the question. The mark value for the question will show how much supplementary comment should be given.
3. *State*: give a concise answer with little or no supporting argument (for example, a numerical answer that can easily be obtained 'by inspection').
4. *List*: give a number of points, generally each of one word. Do not give more points than the number specified.
5. (a) *Explain*: this may imply reasoning or some reference to theory, depending on the context. It is another way of asking candidates to *give reasons for*. The candidate needs to make sure that the examiner is told **why** something happens.

   (b) *Give a reason/Give reasons*: this is another way of asking candidates to explain **why** something happens.
6. (a) *Describe*: state in words the key points that can be found from the data or information given in a graph, table or diagram. Where possible, the candidate should refer to numbers taken from the material.

   (b) *Describe a process*: give a step by step description of what happens during the process.

   Describe and *explain* may be used together, as may *state* and *explain*.
7. *Discuss*: the candidate should give a critical account of the points involved in the topic.
8. *Outline*: the candidate should be brief, restricting the answer to giving essentials, without supporting details.
9. *Predict*: the candidate should produce the required answer by making a logical connection between other pieces of information. The question may provide this information, or the information may depend on answers calculated in an earlier part of the question. The answer should be concise, with no supporting statement required.
10. *Deduce*: the candidate should follow the guidance for *predict*, but a supporting statement is also required: for example, reference to a law, a principle or the necessary reasoning should be included in the answer.
11. (a) *Suggest*: this may imply that there is no single correct answer (for example, in biology, there are a number of factors that might limit the rate of photosynthesis in a plant in a glasshouse).

    (b) *Suggest*: this may also imply that the candidate must apply their general knowledge and understanding of biology to a 'novel' situation, one that may not formally be 'in the syllabus'. Many data-response and problem-solving questions are of this type.
12. *Find*: a general term that can be interpreted as *calculate*, *measure*, *determine*, etc.
13. *Calculate*: a numerical answer is required. In general, working should be shown, especially where two or more steps are involved. The candidate should give suitable units where possible.
14. *Measure*: this implies that a suitable measuring instrument will give the quantity in question: for example, length, using a rule, or mass, using a balance. The candidate should give suitable units where possible.

15. *Determine*: this often implies that the quantity in question cannot be measured directly but must be found by calculation, placing measured or known values of other quantities into a standard formula. It may also be used when the candidate must carry out a procedure to find a numerical answer. For example, the candidate might be asked to find the energy absorbed by a plant and calculate its efficiency.
16. *Estimate*: the candidate should give a reasoned order of magnitude statement or calculation of the quantity in question, making any necessary simplifying assumptions about points of principle and about the values of quantities not otherwise included in the question.
17. *Show*: the candidate must make an algebraic deduction to prove a given equation. The candidate must make sure to state clearly the terms being used.
18. (a) *Sketch, when applied to graph work*: this implies that the shape and/or position of the curve only needs to be qualitatively correct. However, the candidate should be aware that, depending on the context, some quantitative aspects may be looked for, such as passing through the origin or having an intercept, asymptote or discontinuity at a particular value. On a sketch graph, the candidate must show clearly what is being plotted on each axis.

    (b) S*ketch when applied to diagrams*: this implies that simple, freehand drawing is allowed. However, the candidate should take care over proportions and should show important details clearly.
19. *Compare*: the candidate must give **both** the similarities and differences between things or concepts.
20. *Recognise*: the candidate should identify facts, characteristics or concepts that are relevant and/or appropriate to understanding a situation, event, process or phenomenon.
21. *Classify*: the candidate should group things based on common characteristics.

In all questions, **the number of marks** are shown on the examination paper and **candidates should use these as a guide to how much detail to give**. When describing a process, the candidate should use the number of marks to decide **how many steps** to include. When explaining why something happens, the candidate should use the number of marks to decide **how many reasons** to give, or how much detail to give for each reason.

9. Other information

Equality and inclusion

Cambridge International Examinations has taken great care in the preparation of this syllabus and assessment materials to avoid bias of any kind. To comply with the UK Equality Act (2010), Cambridge has designed this qualification with the aim of avoiding direct and indirect discrimination.

The standard assessment arrangements may present unnecessary barriers for candidates with disabilities or learning difficulties. Arrangements can be put in place for these candidates to enable them to access the assessments and receive recognition of their attainment. Access arrangements will not be agreed if they give candidates an unfair advantage over others or if they compromise the standards being assessed.

Candidates who are unable to access the assessment of any component may be eligible to receive an award based on the parts of the assessment they have taken.

Information on access arrangements is found in the *Cambridge Handbook* which can be downloaded from the website **www.cie.org.uk**

Language

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

Grading and reporting

Cambridge International A Level results are shown by one of the grades A*, A, B, C, D or E, indicating the standard achieved, A* being the highest and E the lowest. 'Ungraded' indicates that the candidate's performance fell short of the standard required for grade E. 'Ungraded' will be reported on the statement of results but not on the certificate. The letters Q (result pending); X (no results) and Y (to be issued) may also appear on the statement of results but not on the certificate.

Cambridge International AS Level results are shown by one of the grades a, b, c, d or e, indicating the standard achieved, 'a' being the highest and 'e' the lowest. 'Ungraded' indicates that the candidate's performance fell short of the standard required for grade 'e'. 'Ungraded' will be reported on the statement of results but not on the certificate. The letters Q (result pending); X (no results) and Y (to be issued) may also appear on the statement of results but not 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 these components was sufficient to merit the award of a Cambridge International AS Level grade.

For languages other than English, Cambridge also reports separate speaking endorsement grades (Distinction, Merit and Pass), for candidates who satisfy the conditions stated in the syllabus.

Entry codes

To maintain the security of our examinations we produce question papers for different areas of the world, known as 'administrative zones'. Where the component entry code has two digits, the first digit is the component number given in the syllabus. The second digit is the location code, specific to an administrative zone. Information about entry codes, examination timetables and administrative instructions for your administrative zone can be found in the *Cambridge Guide to Making Entries*.

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