CAMBRIDGE
International Examinations

Cambridge International AS & A Level

SYLLABUS

Cambridge International AS and A Level Biology

9700

For examination in June and November 2016, 2017 and 2018.
Also available for examination in March 2016, 2017 and 2018 for India only.

Cambridge Advanced

What has changed in Cambridge International AS and A Level Biology 9700 for 2016?

- Key concepts: The section 'Why Cambridge International AS and A Level Biology?', on page 5, sets out the key concepts that this syllabus is designed to develop.
- Assessment objectives: There has been a change in the weighting of the assessment objectives (AOs) so that AO1 (Knowledge with understanding) is now 40% instead of 45% and AO2 (Handling information and solving problems) is now 37% instead of 32%. Additionally there have been some minor changes to the descriptions of these assessment objectives.
- The mathematical requirements for this syllabus have changed and details can be found on pages 70–73.
- Syllabus content: This has been reviewed and reorganised. In particular, the applications learning outcomes (topics Q to U previously) have been inserted into other topics alongside the relevant theory.
  - Any new learning outcomes or significant changes are indicated by black vertical lines.
  - Learning outcomes that have been moved, either within a topic or from one topic to another, and learning outcomes with minor changes in wording, will not be indicated by black vertical lines either side of the text. You are advised to read the whole of this syllabus before planning your teaching programme.
  - Learning outcomes that have been removed, and contain content that is not covered elsewhere in the syllabus, and learning outcomes that have changed level (from AS Level to A Level or from A Level to AS Level) are listed on page 78.

This syllabus is for examination in 2016, 2017 and 2018.

If candidates have studied the 2015 syllabus please be aware of the following:

- Assessments in the 2016 examination series are based on this revised syllabus.
- Candidates can carry forward the result of their Cambridge International AS Level assessments in 2015 to complete the Cambridge International A Level in 2016. Cambridge International A Level assessments in the 2016 examination series are based on this revised syllabus.
- Assessments for candidates retaking Cambridge International AS or A Level in 2016 are based on this revised syllabus.

Contents

Introduction 2

Welcome
Why Cambridge International Examinations?
Why Cambridge International AS and A Levels?
Why Cambridge International AS and A Level Biology?
Teacher support

1. Syllabus overview 9

1.1 Content
1.2 Assessment

2. Syllabus aims and assessment objectives 12

2.1 Syllabus aims
2.2 Assessment objectives
2.3 Relationship between assessment objectives and components
2.4 Relationship between assessment objectives and qualifications

3. Syllabus content 16

AS Level Syllabus content
A Level Syllabus content

4. Practical assessment 47

4.1 Introduction
4.2 Paper 3
4.3 Paper 5

5. General syllabus requirements and information 70

5.1 Mathematical requirements
5.2 Glossary of command words

6. Other information 76

Equality and inclusion
Language
Grading and reporting
Entry codes

Welcome

Cambridge International AS and A Level Biology encourages learners to explore their subject in depth. The syllabus has been designed, in consultation with teachers and universities, to help learners develop not only subject knowledge, but also a strong understanding of some of the key concepts that are critical to mastering the subject.

All 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. Consultation is an important part of the way we develop our syllabuses.

Consulting teachers

Teachers at Cambridge schools worldwide help us to shape our Cambridge International AS and A Level syllabuses. The feedback contributes to the development of syllabus content, assessments and support materials. Consulting teachers ensures that our materials are designed carefully around their needs and the needs of their learners.

Consulting universities

Like teachers, universities help to shape our Cambridge International AS and A Level syllabuses. We consult with leading higher education institutions to make sure the syllabuses encourage learners to get a firm grasp of the subject's key concepts and develop the skills necessary for success at university.

Key concepts

Key concepts are essential ideas, theories, principles or mental tools that help learners to develop a deep understanding of their subject and make links between the different topics. The key concepts that this syllabus is designed to develop are detailed on page 5. The teaching support package helps teachers integrate the key concepts into their teaching, showing how they fit into the overall syllabus and suggesting ways to teach them with each topic.

Teacher support

Our comprehensive teacher support will help you deliver the syllabus confidently and effectively. The support includes resources for teaching and learning as well as exam preparation. Learn more on page 8.

> "Cambridge International AS and A Levels prepare students well for university because they've learnt to go into a subject in considerable depth. There's that ability to really understand the depth and richness and the detail of a subject. It's a wonderful preparation for what they are going to face at university."
>
> Christoph Guttentag, Dean of Undergraduate Admissions, Duke University, USA

Back to contents page

Why Cambridge International Examinations?

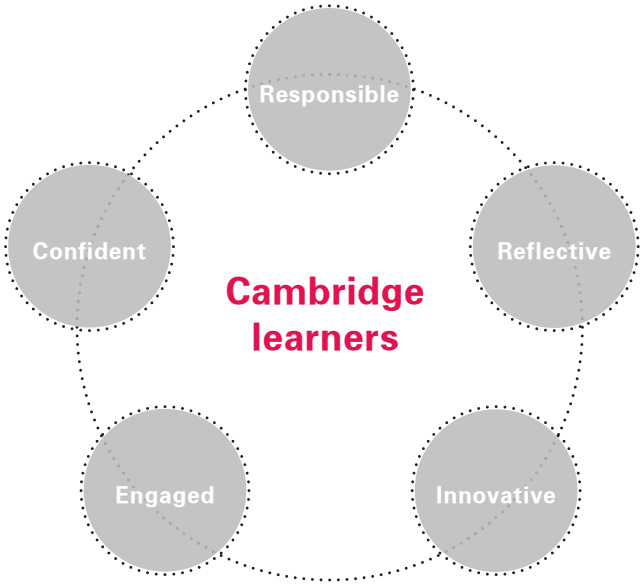
Cambridge International Examinations is the world's largest provider of international education programmes and qualifications for 5 to 19 year olds. We are a part of Cambridge Assessment, a department of the University of Cambridge, trusted for excellence in education, and a not-for-profit organisation. We invest constantly in research and development to improve our programmes and qualifications.

We understand education. More than 9000 schools in over 160 countries are part of our Cambridge learning community. We are committed to providing qualifications that are relevant, accurate, reliable, affordable and recognised by universities and employers worldwide. Learners are at the heart of what we do and we are committed to their development and future success.

Cambridge learners

Cambridge programmes and qualifications develop not only content but also skills. We help learners to bridge the gap to the next stage of education and the world of work. We encourage Cambridge learners to be:

- 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.



Learn more about the Cambridge learner attributes in Chapter 2 of our *Implementing the curriculum with Cambridge* guide at **www.cie.org.uk/curriculumguide**

Why Cambridge International AS and A Levels?

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 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.

Cambridge International AS and A Level curricula are flexible. It is possible to offer almost any combination from a wide range of subjects. Cambridge International A Level is typically a two-year course, and Cambridge International AS Level is typically one year. Some subjects can be started as a Cambridge International AS Level and extended to a Cambridge International A Level.

There are three possible assessment approaches for Cambridge International AS and A Level:

Learners take the Cambridge International AS Level only. The syllabus content for Cambridge International AS Level is half of a Cambridge International A Level programme.

Learners take the Cambridge International AS Level in Year 1 and in Year 2 complete the Cambridge International A Level.

Learners take all papers of the Cambridge International A Level course in the same examination series, usually at the end of the second year of study.

Every year thousands of learners with Cambridge International AS and A Levels gain places at leading universities worldwide. Cambridge International AS and A Levels are accepted and valued by top universities around the world including those in the UK, US (including Ivy League universities), European nations, Australia, Canada and New Zealand. Learners should check the university website for specific entry requirements before applying.

Did you know?

Many universities accept Cambridge International AS Levels in their own right as qualifications counting towards entry to courses in the same or other related subjects. Many learners who take Cambridge International AS Levels also choose to progress to Cambridge International A Level.

Back to contents page

Why Cambridge International AS and A Level Biology?

Universities value learners who have a thorough understanding of key concepts in biology, an in-depth knowledge of biology's most important themes and strong practical skills. Cambridge International AS and A Level Biology helps learners develop the knowledge and skills that will prepare them for successful university study.

Our learners also develop lifelong skills of scientific enquiry, confidence in technology, and communication and teamwork skills.

Key concepts

The key concepts on which this syllabus is built are set out below. These key concepts can help teachers think about how to approach each syllabus topic in order to encourage learners to make links between topics and develop a deep overall understanding of the subject. The teaching support package gives teachers guidance on integrating the key concepts into their teaching. See page 8 for more information on our teacher support.

As a teacher, you will refer to these concepts again and again to help unify the subject and make sense of it. If mastered, learners can use the concepts to solve problems or to understand unfamiliar subject-related material.

- Cells as the units of life
  A cell is the basic unit of life and all organisms are composed of one or more cells. There are two fundamental types of cell: prokaryotic and eukaryotic.
- Biochemical processes
  Cells are dynamic: biochemistry and molecular biology help to explain how and why cells function as they do.
- DNA, the molecule of heredity
  Cells contain the molecule of heredity, DNA. Heredity is based on the inheritance of genes.
- Natural selection
  Natural selection is the major mechanism to explain the theory of evolution.
- Organisms in their environment
  All organisms interact with their biotic and abiotic environment.
- Observation and experiment
  The different fields of biology are intertwined and cannot be studied in isolation: observation and enquiry, experimentation and fieldwork are fundamental to biology.

Guided learning hours

Guided learning hours give an indication of the amount of contact time teachers need to have with learners to deliver a particular course. Our syllabuses are designed around 180 guided learning hours for Cambridge International AS Level, and around 360 guided learning hours for Cambridge International A Level.

These figures are for guidance only. The number of hours needed to gain the qualification may vary depending on local practice and the learners' previous experience of the subject.

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 Co-ordinated Science.

Progression

Cambridge International A Level Biology provides a suitable foundation for the study of biology or related courses in higher education. It is equally 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 then 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.

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 more about the benefits of becoming a Cambridge school from our website 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.

Back to contents page

Cambridge AICE

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 balanced curriculum by recognising the achievements of candidates who pass examinations from different curriculum groups.

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.

Learn more

For more details go to **www.cie.org.uk/qualifications/aice**

> “Our research has shown that students who came to the university with a Cambridge AICE background performed better than anyone else that came to the university. That really wasn’t surprising considering the emphasis they have on critical research and analysis, and that’s what we require at university.”
>
> **John Barnhill**, Assistant Vice President for Enrolment Management, Florida State University, USA

Teacher support

We offer a wide range of practical and innovative support to help teachers plan and deliver our programmes and qualifications confidently.

The support package for our Cambridge International AS and A Levels will help teachers integrate key concepts into their teaching, showing how they fit into the overall syllabus and suggesting ways to teach them within each topic. It also gives teachers access to a worldwide teaching community enabling them to connect with other teachers, swap ideas and share best practice.

We offer a customised support package for each subject. Find out more about the specific support for this syllabus at **www.cie.org.uk/alevelsupport**

Cambridge International AS and A Level support for teachers

Teaching and learning resources

- Schemes of work provide teachers with a medium-term plan with ideas on how to deliver the course.
- Endorsed textbooks produced by leading publishers. We have quality checked these materials to make sure that they match the syllabus well.
- Resource lists to help support teaching, including textbooks and websites.

Exam preparation resources

- Past question papers and mark schemes so teachers can give your learners the opportunity to practise answering different questions.
- Example candidate responses to help teachers to see the level of performance needed to achieve key grades and understand exactly what examiners are looking for.
- Principal examiner reports describing learners' overall performance on each part of the papers. The reports give insight into common misconceptions shown by learners, which teachers can address in lessons.

Professional development

Face-to-face training
We hold workshops around the world to support teachers in delivering Cambridge syllabuses and developing their skills.

Online training
We offer self-study and tutor-led online training courses via our virtual learning environment. A wide range of syllabus-specific courses and skills courses is available. We also offer training via video conference and webinars.

Qualifications
We offer a wide range of practice-based qualifications at Certificate and Diploma level, providing a framework for continuing professional development.

Learn more

Find out more about specific support for this syllabus at www.cie.org.uk/alevelsupport

Visit our online resource bank and community forum at teachers.cie.org.uk

Useful links

Customer Services www.cie.org.uk/help
LinkedIn http://linkd.in/cambridgeteacher
Twitter @cie_education
Facebook www.facebook.com/cie.org.uk

Back to contents page

1. Syllabus overview

1.1 Content

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

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

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

12 Energy and respiration
13 Photosynthesis
14 Homeostasis
15 Control and co-ordination
16 Inherited change
17 Selection and evolution
18 Biodiversity, classification and conservation
19 Genetic technology

1.2 Assessment

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 examination series.

Candidates who, having received AS certification, wish to continue their studies to the full Advanced Level qualification may carry their AS marks forward and take Papers 4 and 5 in the examination series in which they require certification.

Candidates taking the full Advanced Level qualification at the end of the course take all five papers in a single examination 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 resit purposes.

All components will be externally assessed.

Component	Weighting	
	AS Level	A Level
Paper 1 Multiple Choice **1 hour** This paper consists of 40 multiple choice questions, all with four options. All questions will be based on the AS Level syllabus content. Candidates will answer all questions. Candidates will answer on an answer sheet. [40 marks]	31%	15.5%
Paper 2 AS Level Structured Questions **1 hour 15 minutes** This paper consists of a variable number of questions, of variable mark value. All questions will be based on the AS Level syllabus content. Candidates will answer all questions. Candidates will answer on the question paper. [60 marks]	46%	23%
Paper 3 Advanced Practical Skills **2 hours** This paper requires candidates to carry out practical work in timed conditions. This paper will consist of two or three experiments drawn from different areas of the AS Level syllabus. Candidates will answer all questions. Candidates will answer on the question paper. [40 marks]	23%	11.5%
Paper 4 A Level Structured Questions **2 hours** This paper consists of a variable number of structured questions each with a variable mark value (Section A) and a choice of one free response style question worth 15 marks (Section B). All questions will be based on the A Level syllabus but may require knowledge of material first encountered in the AS Level syllabus. Candidates will answer on the question paper. [100 marks]	–	38.5%
Paper 5 Planning, Analysis and Evaluation **1 hour 15 minutes** This paper consists of a variable number of questions of variable mark value based on the practical skills of planning, analysis and evaluation. Candidates will answer on the question paper. [30 marks]	–	11.5%

Back to contents page

Nomenclature

Symbols, signs and abbreviations used in examination papers will follow the recommendations made in the ASE publication *Signs, Symbols and Systematics* (The ASE Companion to 16–19 Science, 2000).

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.

Units

In practical work, candidates will be expected to use SI units or, where appropriate, units approved by the BIPM for use with the SI (e.g. minute). A list of SI units and units approved for use with the SI may be found in the SI brochure at **www.bipm.org**. The use of imperial/customary units, such as the inch and degree Fahrenheit, is not acceptable and should be discouraged. In all examinations, where data are supplied for use in questions, candidates will be expected to use units that are consistent with the units supplied and should not attempt conversion to other systems of units unless it is a requirement of the question.

Concepts of physical science

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

Availability

This syllabus is examined in the May/June examination series and the October/November examination series. The syllabus is also available for examination in March for India only.

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.

2. Syllabus aims and assessment objectives

2.1 Syllabus aims

The aims below are not listed in order of priority. The aims of a course based on this syllabus should be to:

1. provide, through well-designed studies of experimental and practical biological science, a worthwhile educational experience for all learners, 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 science 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 efficient and safe practice
   - encourage effective communication using universal scientific conventions.
3. develop attitudes relevant to biological science such as:
   - a concern for accuracy and precision
   - objectivity
   - integrity
   - a spirit of enquiry
   - initiative
   - inventiveness.
4. stimulate interest in, and care for, the local and global environment and help learners to understand the need for conservation.
5. promote an awareness 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
   - the study and practice of biology are affected and limited by social, economic, technological, ethical and cultural factors
   - the applications of biological science may be both helpful and harmful to the individual, the community and the environment.
   - The use of information technology is important for communication, as an aid to experiments and as a tool for interpreting experimental and theoretical results.
6. stimulate learners and create a sustained interest in biology so that the study of the subject is enjoyable and satisfying.

Back to contents page

2.2 Assessment objectives

The assessment objectives listed below reflect those parts of the syllabus aims that will be assessed in the examination.

AO1 Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of:

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

The subject content defines the factual knowledge that candidates may be required to recall and explain.

Questions testing these assessment objectives will often begin with one of the following words: *define*, *state*, *name*, *describe*, *explain (using your knowledge and understanding)* or *outline* (see Glossary of command words in Section 5).

AO2 Handling information and solving problems

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

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

These assessment objectives cannot be precisely specified in the syllabus content because questions testing such skills may be based on information which is unfamiliar to the candidate. In answering such questions, candidates are required to 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 assessment 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 Glossary of command words in Section 5).

AO3 Experimental skills and investigations

Candidates should be able to:

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

2.3 Relationship between assessment objectives and components

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

The table shows the assessment objectives (AO) as a percentage of each component.

Component	AO1 %	AO2 %	AO3 %
Paper 1	52	48	0
Paper 2	52	48	0
Paper 3	0	0	100
Paper 4	52	48	0
Paper 5	0	0	100

2.4 Relationship between assessment objectives and qualifications

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

The table shows the assessment objectives (AO) as a percentage of each qualification.

Assessment objective	Weighting in AS Level %	Weighting in A Level %
AO1	40	40
AO2	37	37
AO3	23	23

The weighting table gives a general idea of how marks are allocated to assessment objectives in the different components. However, the balance on each paper may vary slightly.

Back to contents page

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' (AO1) and the 'Handling information and solving problems' (AO2) categories.

Teachers should note that there is a greater weighting of 60% for skills (including handling information, solving problems, experimental skills and investigations) compared to 40% 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.

3. Syllabus content

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

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

Teachers should include the social, environmental, economic and technological aspects of biology wherever possible throughout the syllabus (see Aims 4 and 5 on page 12). Some examples are included in the syllabus, and teachers should encourage learners to apply the principles of these examples to other situations introduced in the course.

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

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

Support for teaching practical skills for these qualifications can be found on the Cambridge Teacher Support website **www.cie.org.uk/alevelsupport**

Back to contents page

AS Level Syllabus content

1 Cell structure

All organisms are composed of cells. Knowledge of their structure and function underpins much of biology. The fundamental differences between eukaryotic and prokaryotic cells are explored and provide useful biological background for the section on Infectious disease. Viruses are introduced as non-cellular structures, which gives candidates the opportunity to consider whether cells are a fundamental property of life.

The use of light microscopes is a fundamental skill that is developed in this section and applied throughout several other sections of the syllabus. Throughout the course, photomicrographs and electron micrographs from transmission and scanning electron microscopes should be studied.

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
1.1 The microscope in cell studies An understanding of the principles of microscopy shows why light and electron microscopes have been essential in improving our knowledge of cells.	a) compare the structure of typical animal and plant cells by making temporary preparations of live material and using photomicrographs b) calculate the linear magnifications of drawings, photomicrographs and electron micrographs c) use an eyepiece graticule and stage micrometer scale to measure cells and be familiar with units (millimetre, micrometre, nanometre) used in cell studies d) explain and distinguish between resolution and magnification, with reference to light microscopy and electron microscopy e) calculate actual sizes of specimens from drawings, photomicrographs and electron micrographs

1.2 Cells as the basic units of living organisms

The cell is the basic unit of all living organisms. The interrelationships between these cell structures show how cells function to transfer energy, produce biological molecules including proteins and exchange substances with their surroundings.

Prokaryotic cells and eukaryotic cells share some features, but the differences between them illustrate the divide between these two cell types.

a) describe and interpret electron micrographs and drawings of typical animal and plant cells as seen with the electron microscope

b) recognise the following cell structures and outline their functions:

- cell surface membrane
- nucleus, nuclear envelope and nucleolus
- rough endoplasmic reticulum
- smooth endoplasmic reticulum
- Golgi body (Golgi apparatus or Golgi complex)
- mitochondria (including small circular DNA)
- ribosomes (80S in the cytoplasm and 70S in chloroplasts and mitochondria)
- lysosomes
- centrioles and microtubules
- chloroplasts (including small circular DNA)
- cell wall
- plasmodesmata
- large permanent vacuole and tonoplast of plant cells

c) state that ATP is produced in mitochondria and chloroplasts and outline the role of ATP in cells

d) outline key structural features of typical prokaryotic cells as seen in a typical bacterium (including: unicellular, 1-5μm diameter, peptidoglycan cell walls, lack of organelles surrounded by double membranes, naked circular DNA, 70S ribosomes)

e) compare and contrast the structure of typical prokaryotic cells with typical eukaryotic cells (reference to mesosomes should not be included)

f) outline the key features of viruses as non-cellular structures (limited to protein coat and DNA/RNA)

Back to contents page

2 Biological molecules

This section introduces carbohydrates, proteins and lipids: organic molecules that are important in cells. Nucleic acids are covered in a separate section. Biological molecules are based on the versatile element carbon. This section explains how macromolecules, which have a great diversity of function in organisms, are assembled from smaller organic molecules such as glucose, amino acids, glycerol and fatty acids.

Life as we know it would not be possible without water. Understanding the properties of this extraordinary molecule is an essential part of any study of biological molecules.

The emphasis in this section is on the relationship between molecular structures and their functions. Some of these ideas are continued in other sections, for example, the functions of haemoglobin in gas transport in Transport of mammals, phospholipids in membranes in Cell membranes and transport and antibodies in Immunity.

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
2.1 Testing for biological molecules Tests for biological molecules can be used in a variety of contexts, such as identifying the contents of mixtures of molecules and following the activity of digestive enzymes.	a) carry out tests for reducing sugars and non-reducing sugars, the iodine in potassium iodide solution test for starch, the emulsion test for lipids and the biuret test for proteins to identify the contents of solutions b) carry out a semi-quantitative Benedict's test on a reducing sugar using dilution, standardising the test and using the results (colour standards or time to first colour change) to estimate the concentration
2.2 Carbohydrates and lipids Carbohydrates and lipids have important roles in the provision and storage of energy and for a variety of other functions such as providing barriers around cells: the phospholipid bilayer of all cell membranes and the cellulose cell walls of plant cells.	a) describe the ring forms of α-glucose and β-glucose b) define the terms monomer, polymer, macromolecule, monosaccharide, disaccharide and polysaccharide c) describe the formation of a glycosidic bond by condensation, with reference both to polysaccharides and to disaccharides, including sucrose d) describe the breakage of glycosidic bonds in polysaccharides and disaccharides by hydrolysis, with reference to the non-reducing sugar test e) describe the molecular structure of polysaccharides including starch (amylose and amylopectin), glycogen and cellulose and relate these structures to their functions in living organisms f) describe the molecular structure of a triglyceride with reference to the formation of ester bonds and relate the structure of triglycerides to their functions in living organisms g) describe the structure of a phospholipid and relate the structure of phospholipids to their functions in living organisms

2.3 Proteins and water An understanding of protein structure and how it is related to function is central to many aspects of biology, such as enzymes, antibodies and muscle contraction. Globular and fibrous proteins play important roles in biological processes such as the transport of gases and providing support for tissues. Water is a special molecule with extraordinary properties that make life possible on this planet 150 million kilometres from the Sun.	a) describe the structure of an amino acid and the formation and breakage of a peptide bond b) 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 these molecules in shape c) 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 two alpha (α) chains and two 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) d) explain how hydrogen bonding occurs between water molecules and relate the properties of water to its roles in living organisms (limited to solvent action, specific heat capacity and latent heat of vapourisation)

Back to contents page

3 Enzymes

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

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

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
3.1 Mode of action of enzymes There are many different enzymes, each one specific to a particular reaction. This specificity is the key to understanding the efficient functioning of cells and living organisms.	a) explain that enzymes are globular proteins that catalyse metabolic reactions b) state that enzymes function inside cells (intracellular enzymes) and outside cells (extracellular enzymes) c) 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) d) investigate 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)
3.2 Factors that affect enzyme action Investigating the effects of factors on enzyme activity gives opportunities for planning and carrying out experiments under controlled conditions.	a) investigate and explain the effects of the following factors on the rate of enzyme-catalysed reactions: • temperature • pH (using buffer solutions) • enzyme concentration • substrate concentration • inhibitor concentration b) explain that the maximum rate of reaction (V_{max}) is used to derive the Michaelis-Menten constant (K_m) which is used to compare the affinity of different enzymes for their substrates c) explain the effects of reversible inhibitors, both competitive and non-competitive, on the rate of enzyme activity d) investigate and explain the effect of immobilising an enzyme in alginate on its activity as compared with its activity when free in solution

4 Cell membranes and transport

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

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

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
4.1 Fluid mosaic membranes The structure of cell surface membranes allows movement of substances between cells and their surroundings and allows cells to communicate with each other by cell signalling.	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 including references to carrier proteins, channel proteins, cell surface receptors and cell surface antigens c) outline the process of cell signalling involving the release of chemicals that combine with cell surface receptors on target cells, leading to specific responses
4.2 Movement of substances into and out of cells The fluid mosaic model allows an understanding of how substances enter and exit cells by a variety of different mechanisms. Investigating the effect of increasing the size of model cells allows an understanding of the constraints of obtaining resources across the cell surface and moving substances out of cells.	a) describe and explain the processes of diffusion, facilitated diffusion, osmosis, active transport, endocytosis and exocytosis (no calculations involving water potential will be set) b) investigate simple diffusion using plant tissue and non-living materials, such as glucose solutions, Visking tubing and agar c) calculate surface areas and volumes of simple shapes (e.g. cubes) to illustrate the principle that surface area to volume ratios decrease with increasing size d) investigate the effect of changing surface area to volume ratio on diffusion using agar blocks of different sizes e) investigate the effects of immersing plant tissues in solutions of different water potential, using the results to estimate the water potential of the tissues f) explain the movement of water between cells and solutions with different water potentials and explain the different effects on plant and animal cells

Back to contents page

5 The mitotic cell cycle

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

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

		Learning outcomes Candidates should be able to:
5.1	**Replication and division of nuclei and cells** During the mitotic cell cycle, DNA is replicated and passed to daughter cells. Stem cells in bone marrow and the skin continually divide by mitosis to provide a continuous supply of cells that differentiate into blood and skin cells.	a) describe the structure of a chromosome, limited to DNA, histone proteins, chromatids, centromere and telomeres b) explain the importance of mitosis in the production of genetically identical cells, growth, cell replacement, repair of tissues and asexual reproduction c) outline the cell cycle, including interphase (growth and DNA replication), mitosis and cytokinesis d) outline the significance of telomeres in permitting continued replication and preventing the loss of genes e) outline the significance of mitosis in cell replacement and tissue repair by stem cells and state that uncontrolled cell division can result in the formation of a tumour
5.2	**Chromosome behaviour in mitosis** The events that occur during mitosis can be followed by using a light microscope.	a) describe, with the aid of photomicrographs and diagrams, the behaviour of chromosomes in plant and animal cells during the mitotic cell cycle and the associated behaviour of the nuclear envelope, cell surface membrane and the spindle (names of the main stages of mitosis are expected) b) observe and draw the mitotic stages visible in temporary root tip squash preparations and in prepared slides of root tips of species such as those of *Vicia faba* and *Allium cepa*

6 Nucleic acids and protein synthesis

Nucleic acids have roles in the storage and retrieval of genetic information and in the use of this information to synthesise polypeptides. DNA is an extremely stable molecule that cells replicate with extreme accuracy. The genetic code is used by cells for assembling amino acids in correct sequences to make polypeptides. In eukaryotes this involves the processes of transcription in the nucleus to produce short-lived molecules of messenger RNA followed by translation in the cytoplasm.

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
6.1 Structure and replication of DNA Understanding the structure of nucleic acids allows an understanding of their role in the storage of genetic information and how that information is used in the synthesis of proteins.	a) describe the structure of nucleotides, including the phosphorylated nucleotide ATP (structural formulae are not required) b) describe the structure of RNA and DNA and explain the importance of base pairing and the different hydrogen bonding between bases (include reference to adenine and guanine as purines and to cytosine, thymine and uracil as pyrimidines. Structural formulae for bases are not required but the recognition that purines have a double ring structure and pyrimidines have a single ring structure should be included) c) describe the semi-conservative replication of DNA during interphase
6.2 Protein synthesis The genetic code specifies the amino acids that are assembled to make polypeptides. The way that DNA codes for polypeptides is central to our understanding of how cells and organisms function.	a) state that a polypeptide is coded for by a gene and that a gene is a sequence of nucleotides that forms part of a DNA molecule b) state that a gene mutation is a change in the sequence of nucleotides that may result in an altered polypeptide c) describe the way in which the nucleotide sequence codes for the amino acid sequence in a polypeptide with reference to the nucleotide sequence for Hb^A (normal) and Hb^S (sickle cell) alleles of the gene for the β-globin polypeptide d) describe how the information in DNA is used during transcription and translation to construct polypeptides, including the role of messenger RNA (mRNA), transfer RNA (tRNA) and the ribosomes

Back to contents page

7 Transport in plants

Flowering plants do not have compact bodies like those of animals. Leaves and extensive root systems spread out to obtain the light energy, water, mineral ions and carbon dioxide that plants gain from their environment to make organic molecules, such as sugars and amino acids. Transport systems in plants move substances from where they are absorbed or produced to where they are stored or used. Plants do not have systems for transporting oxygen and carbon dioxide; instead these gases diffuse through air spaces within stems, roots and leaves.

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
7.1 Structure of transport tissues Plants have two transport tissues: xylem and phloem.	a) draw and label from prepared slides plan diagrams of transverse sections of stems, roots and leaves of herbaceous dicotyledonous plants using an eyepiece graticule to show tissues in correct proportions (see 1.1c) b) draw and label from prepared slides the cells in the different tissues in roots, stems and leaves of herbaceous dicotyledonous plants using transverse and longitudinal sections c) draw and label from prepared slides the structure of xylem vessel elements, phloem sieve tube elements and companion cells and be able to recognise these using the light microscope d) relate the structure of xylem vessel elements, phloem sieve tube elements and companion cells to their functions

7.2 Transport mechanisms

Movement of xylem sap and phloem sap is by mass flow. Movement in the xylem is passive as it is driven by evaporation from the leaves; plants use energy to move substances in the phloem.

Xylem sap moves in one direction from the roots to the rest of the plant. The phloem sap in a phloem sieve tube moves in one direction from the location where it is made to the location where it is used or stored. At any one time phloem sap can be moving in different directions in different sieve tubes.

a) explain the movement of water between plant cells, and between them and their environment, in terms of water potential (see 4.2. No calculations involving water potential will be set)

b) explain how hydrogen bonding of water molecules is involved with movement in the xylem by cohesion-tension in transpiration pull and adhesion to cellulose cell walls

c) describe the pathways and explain the mechanisms by which water and mineral ions are transported from soil to xylem and from roots to leaves (include reference to the symplastic pathway and apoplastic pathway and Casparian strip)

d) define the term transpiration and explain that it is an inevitable consequence of gas exchange in plants

e) investigate experimentally and explain the factors that affect transpiration rate using simple potometers, leaf impressions, epidermal peels, and grids for determining surface area

f) make annotated drawings, using prepared slides of cross-sections, to show how leaves of xerophytic plants are adapted to reduce water loss by transpiration

g) state that assimilates, such as sucrose and amino acids, move between sources (e.g. leaves and storage organs) and sinks (e.g. buds, flowers, fruits, roots and storage organs) in phloem sieve tubes

h) explain how sucrose is loaded into phloem sieve tubes by companion cells using proton pumping and the co-transporter mechanism in their cell surface membranes

i) explain mass flow in phloem sap down a hydrostatic pressure gradient from source to sink

Back to contents page

8 Transport in mammals

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

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
8.1 The circulatory system The mammalian circulatory system consists of a pump, many blood vessels and blood, which is a suspension of red blood cells and white blood cells in plasma.	a) state that the mammalian circulatory system is a closed double circulation consisting of a heart, blood vessels and blood b) observe and make plan diagrams of the structure of arteries, veins and capillaries using prepared slides and be able to recognise these vessels using the light microscope c) explain the relationship between the structure and function of arteries, veins and capillaries d) observe and draw the structure of red blood cells, monocytes, neutrophils and lymphocytes using prepared slides and photomicrographs e) state and explain the differences between blood, tissue fluid and lymph f) describe the role of haemoglobin in carrying oxygen and carbon dioxide with reference to the role of carbonic anhydrase, the formation of haemoglobinic acid and carbaminohaemoglobin (details of the chloride shift are not required) g) describe and explain the significance of the oxygen dissociation curves of adult oxyhaemoglobin at different carbon dioxide concentrations (the Bohr effect) h) describe and explain the significance of the increase in the red blood cell count of humans at high altitude
8.2 The heart The mammalian heart is a double pump: the right side pumps blood at low pressure to the lungs and the left side pumps blood at high pressure to the rest of the body.	a) describe the external and internal structure of the mammalian heart b) explain the differences in the thickness of the walls of the different chambers in terms of their functions with reference to resistance to flow c) describe the cardiac cycle (including blood pressure changes during systole and diastole) d) explain how heart action is initiated and controlled (reference should be made to the sinoatrial node, the atrioventricular node and the Purkyne tissue, but not to nervous and hormonal control)

9 Gas exchange and smoking

The gas exchange system is responsible for the uptake of oxygen into the blood and excreting carbon dioxide. An understanding of this system shows how cells, tissues and organs function together to exchange these gases between the blood and the environment. The health of this system and of the cardiovascular system is put at risk by smoking.

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
9.1 The gas exchange system The gas exchange surface in the lungs is extensive, very thin, well supplied with blood and well ventilated. The trachea and bronchi provide little resistance to the movement of air to and from the alveoli.	a) describe the gross structure of the human gas exchange system b) observe and draw plan diagrams of the structure of the walls of the trachea, bronchi, bronchioles and alveoli indicating the distribution of cartilage, ciliated epithelium, goblet cells, smooth muscle, squamous epithelium and blood vessels c) describe the functions of cartilage, cilia, goblet cells, mucous glands, smooth muscle and elastic fibres and recognise these cells and tissues in prepared slides, photomicrographs and electron micrographs of the gas exchange system d) describe the process of gas exchange between air in the alveoli and the blood
9.2 Smoking Smoking is one of the major avoidable risk factors of chronic, life-threatening diseases of the gas exchange and circulatory systems.	a) describe the effects of tar and carcinogens in tobacco smoke on the gas exchange system with reference to lung cancer and chronic obstructive pulmonary disease (COPD) b) describe the short-term effects of nicotine and carbon monoxide on the cardiovascular system

Back to contents page

10 Infectious disease

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

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
10.1 Infectious diseases While many infectious diseases have been successfully controlled in some parts of the world, many people worldwide are still at risk of these diseases.	a) define the term disease and explain the difference between an infectious disease and a non-infectious disease (limited to sickle cell anaemia and lung cancer) b) state the name and type of causative organism (pathogen) of each of the following diseases: cholera, malaria, tuberculosis (TB), HIV/AIDS, smallpox and measles (detailed knowledge of structure is not required. For smallpox (*Variola*) and measles (*Morbillivirus*) only the name of genus is needed) c) explain how cholera, measles, malaria, TB and HIV/AIDS are transmitted d) discuss the biological, social and economic 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) 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
10.2 Antibiotics The 'age of antibiotics' began in the 1940s with the availability of penicillin. With an increase in antibiotic resistance is this age about to come to an end?	a) outline how penicillin acts on bacteria and why antibiotics do not affect viruses b) explain in outline how bacteria become resistant to antibiotics with reference to mutation and selection c) discuss the consequences of antibiotic resistance and the steps that can be taken to reduce its impact

11 Immunity

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

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
11.1 The immune system The immune system has non-specific and specific responses to pathogens. Auto-immune diseases are the result of failures in the system to distinguish between self and non-self.	a) state that phagocytes (macrophages and neutrophils) have their origin in bone marrow and describe their mode of action b) describe the modes of action of B-lymphocytes and T-lymphocytes c) describe and explain the significance of the increase in white blood cell count in humans with infectious diseases and leukaemias d) explain the meaning of the term immune response, making reference to the terms antigen, self and non-self e) explain the role of memory cells in long-term immunity f) explain, with reference to myasthenia gravis, that the immune system sometimes fails to distinguish between self and non-self
11.2 Antibodies and vaccination Active and passive immunisations are effective ways to treat and prevent infectious diseases. Smallpox has been eradicated; other diseases may soon follow, but vaccine development has proved more difficult for diseases such as malaria.	a) relate the molecular structure of antibodies to their functions (see 2.3b) b) outline the hybridoma method for the production of monoclonal antibodies c) outline the use of monoclonal antibodies in the diagnosis of disease and in the treatment of disease d) distinguish between active and passive, natural and artificial immunity and explain how vaccination can control disease e) discuss the reasons why vaccination programmes have eradicated smallpox, but not measles, tuberculosis (TB), malaria or cholera

Back to contents page

A Level Syllabus content

12 Energy and respiration

Energy is a fundamental concept in biology. All living things require a source of cellular energy to drive their various activities. ATP is the universal energy currency as its molecules are small, soluble and easily hydrolysed to release energy for cellular activities. All organisms respire to release energy from energy-rich molecules such as glucose and fatty acids and transfer that energy to ATP. Respiration is a series of enzyme-catalysed reactions that release energy in small 'packets'. In eukaryotes, aerobic respiration occurs in mitochondria.

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
12.1 Energy ATP is the universal energy currency as it provides the immediate source of energy for cellular processes.	a) outline the need for energy in living organisms, as illustrated by anabolic reactions, such as DNA replication and protein synthesis, active transport, movement and the maintenance of body temperature b) describe the features of ATP that make it suitable as the universal energy currency c) explain that ATP is synthesised in substrate-linked reactions in glycolysis and in the Krebs cycle d) outline the roles of the coenzymes NAD, FAD and coenzyme A in respiration e) explain that the synthesis of ATP is associated with the electron transport chain on the membranes of mitochondria and chloroplasts (see 12.2g) f) explain the relative energy values of carbohydrate, lipid and protein as respiratory substrates and explain why lipids are particularly energy-rich g) define the term respiratory quotient (RQ) and determine RQs from equations for respiration h) carry out investigations, using simple respirometers, to determine the RQ of germinating seeds or small invertebrates (e.g. blowfly larvae)
12.2 Respiration Respiration is the process whereby energy from complex organic molecules is transferred to ATP.	a) list the four stages in aerobic respiration (glycolysis, link reaction, Krebs cycle and oxidative phosphorylation) and state where each occurs in eukaryotic cells b) outline glycolysis as phosphorylation of glucose and the subsequent splitting of fructose 1,6-bisphosphate (6C) into two triose phosphate molecules, which are then further oxidised to pyruvate with a small yield of ATP and reduced NAD c) explain that, when oxygen is available, pyruvate is converted into acetyl (2C) coenzyme A in the link reaction

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

e) explain that reactions in the Krebs cycle involve decarboxylation and dehydrogenation and the reduction of NAD and FAD

f) outline the process of oxidative phosphorylation including the role of oxygen as the final electron acceptor (no details of the carriers are required)

This process of ATP synthesis using the energy in proton gradients is common to both respiration and photosynthesis.

g) explain that during oxidative phosphorylation:
- energetic electrons release energy as they pass through the electron transport system
- the released energy is used to transfer protons across the inner mitochondrial membrane
- protons return to the mitochondrial matrix by facilitated diffusion through ATP synthase providing energy for ATP synthesis (details of ATP synthase are not required)

h) carry out investigations to determine the effect of factors such as temperature and substrate concentration on the rate of respiration of yeast using a redox indicator (e.g. DCPIP or methylene blue)

i) describe the relationship between structure and function of the mitochondrion using diagrams and electron micrographs

Some organisms and some tissues are able to respire in both aerobic and anaerobic conditions. When yeast and plants respire under anaerobic conditions, they produce ethanol and carbon dioxide as end-products; mammalian muscle tissue produces lactate when oxygen is in short supply.

j) distinguish between respiration in aerobic and anaerobic conditions in mammalian tissue and in yeast cells, contrasting the relative energy released by each (a detailed account of the total yield of ATP from the aerobic respiration of glucose is not required)

k) explain the production of a small yield of ATP from respiration in anaerobic conditions in yeast and in mammalian muscle tissue, including the concept of oxygen debt

l) explain how rice is adapted to grow with its roots submerged in water in terms of tolerance to ethanol from respiration in anaerobic conditions and the presence of aerenchyma

m) carry out investigations, using simple respirometers, to measure the effect of temperature on the respiration rate of germinating seeds or small invertebrates

Back to contents page

13 Photosynthesis

Photosynthesis is the energy transfer process that is the basis of much of life on Earth. It provides the basis of most food chains providing energy directly or indirectly for all other organisms. In eukaryotes, the process occurs within chloroplasts. Candidates use their knowledge of plant cells and leaf structure from the section on Cell structure while studying photosynthesis. Various environmental factors influence the rate at which photosynthesis occurs.

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
13.1 Photosynthesis as an energy transfer process Light energy absorbed by chloroplast pigments in the light dependent stage of photosynthesis is used to drive reactions of the light independent stage that produce complex organic compounds. Chromatography is used to identify chloroplast pigments and was also used to identify the intermediates in the Calvin cycle.	a) explain that energy transferred as ATP and reduced NADP from the light dependent stage is used during the light independent stage (Calvin cycle) of photosynthesis to produce complex organic molecules b) state the sites of the light dependent and the light independent stages in the chloroplast c) describe the role of chloroplast pigments (chlorophyll a, chlorophyll b, carotene and xanthophyll) in light absorption in the grana d) interpret absorption and action spectra of chloroplast pigments e) use chromatography to separate and identify chloroplast pigments and carry out an investigation to compare the chloroplast pigments in different plants (reference should be made to R_f values in identification) f) describe the light dependent stage as the photoactivation of chlorophyll resulting in the photolysis of water and the transfer of energy to ATP and reduced NADP (cyclic and non-cyclic photophosphorylation should be described in outline only) g) outline the three main stages of the Calvin cycle: • fixation of carbon dioxide by combination with ribulose bisphosphate (RuBP), a 5C compound, to yield two molecules of GP (PGA), a 3C compound • the reduction of GP to triose phosphate (TP) involving ATP and reduced NADP • the regeneration of ribulose bisphosphate (RuBP) using ATP h) describe, in outline, the conversion of Calvin cycle intermediates to carbohydrates, lipids and amino acids and their uses in the plant cell

13.2 Investigation of limiting factors Environmental factors influence the rate of photosynthesis. Investigating these shows how they can be managed in protected environments used in crop production.	a) explain the term limiting factor in relation to photosynthesis b) explain the effects of changes in light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis c) explain how an understanding of limiting factors is used to increase crop yields in protected environments, such as glasshouses d) carry out an investigation to determine the effect of light intensity or light wavelength on the rate of photosynthesis using a redox indicator (e.g. DCPIP) and a suspension of chloroplasts (the Hill reaction) e) carry out investigations on the effects of light intensity, carbon dioxide and temperature on the rate of photosynthesis using whole plants, e.g. aquatic plants such as *Elodea* and *Cabomba*
13.3 Adaptations for photosynthesis All the stages of photosynthesis occur in the chloroplast. Some tropical crops have C4 metabolism and adaptations to maximise carbon dioxide fixation.	a) describe the relationship between structure and function in the chloroplast using diagrams and electron micrographs b) 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 spatial separation of initial carbon fixation from the light dependent stage (biochemical details of the C4 pathway are required in outline only) • the high optimum temperatures of the enzymes involved

Back to contents page

14 Homeostasis

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

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
14.1 Homeostasis in mammals Homeostasis in mammals requires complex systems to maintain internal conditions near constant. The kidneys remove wastes from the blood and are the effectors for controlling the water potential of the blood.	a) discuss the importance of homeostasis in mammals and explain the principles of homeostasis in terms of internal and external stimuli, receptors, central control, co-ordination systems, effectors (muscles and glands) b) define the term negative feedback and explain how it is involved in homeostatic mechanisms c) outline the roles of the nervous system and endocrine system in co-ordinating homeostatic mechanisms, including thermoregulation, osmoregulation and the control of blood glucose concentration d) describe the deamination of amino acids and outline the formation of urea in the urea cycle (biochemical detail of the urea cycle is not required) e) describe the gross structure of the kidney and the detailed structure of the nephron with its associated blood vessels using photomicrographs and electron micrographs f) describe how the processes of ultrafiltration and selective reabsorption are involved with the formation of urine in the nephron g) describe the roles of the hypothalamus, posterior pituitary, ADH and collecting ducts in osmoregulation h) explain how the blood glucose concentration is regulated by negative feedback control mechanisms, with reference to insulin and glucagon i) outline the role of cyclic AMP as a second messenger with reference to the stimulation of liver cells by adrenaline and glucagon j) describe the three main stages of cell signalling in the control of blood glucose by adrenaline as follows: • hormone-receptor interaction at the cell surface (see 4.1c) • formation of cyclic AMP which binds to kinase proteins • an enzyme cascade involving activation of enzymes by phosphorylation to amplify the signal

	k) explain the principles of operation of dip sticks containing glucose oxidase and peroxidase enzymes, and biosensors that can be used for quantitative measurements of glucose in blood and urine l) explain how urine analysis is used in diagnosis with reference to glucose, protein and ketones
14.2 Homeostasis in plants Stomatal aperture is regulated in response to the requirements for uptake of carbon dioxide for photosynthesis and conserving water.	a) explain that stomata have daily rhythms of opening and closing and also respond to changes in environmental conditions to allow diffusion of carbon dioxide and regulate water loss by transpiration b) describe the structure and function of guard cells and explain the mechanism by which they open and close stomata c) describe the role of abscisic acid in the closure of stomata during times of water stress (the role of calcium ions as a second messenger should be emphasised)

Back to contents page

15 Control and co-ordination

All the activities of multicellular organisms require co-ordinating, some very rapidly and some more slowly. The nervous system and the endocrine system provide co-ordination in mammals. Similar co-ordination systems exist in plants.

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
15.1 Control and co-ordination in mammals The nervous system provides fast communication between receptors and effectors. Transmission between neurones takes place at synapses.	a) compare the nervous and endocrine systems as communication systems that co-ordinate responses to changes in the internal and external environment (see 14.1a and 14.1b) b) describe the structure of a sensory neurone and a motor neurone c) outline the roles of sensory receptor cells in detecting stimuli and stimulating the transmission of nerve impulses in sensory neurones (a suitable example is the chemoreceptor cell found in human taste buds) d) describe the functions of sensory, relay and motor neurones in a reflex arc e) 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 impulse transmission should be emphasised) f) explain the importance of the myelin sheath (saltatory conduction) in determining the speed of nerve impulses and the refractory period in determining their frequency g) describe the structure of a cholinergic synapse and explain how it functions, including the role of calcium ions h) outline the roles of synapses in the nervous system in allowing transmission in one direction and in allowing connections between one neurone and many others (summation, facilitation and inhibitory synapses are not required) i) describe the roles of neuromuscular junctions, transverse system tubules and sarcoplasmic reticulum in stimulating contraction in striated muscle j) describe the ultrastructure of striated muscle with particular reference to sarcomere structure k) explain the sliding filament model of muscular contraction including the roles of troponin, tropomyosin, calcium ions and ATP
The endocrine system is a slower system that controls long-term changes. Fertility may be controlled by use of hormones.	l) explain the roles of the hormones FSH, LH, oestrogen and progesterone in controlling changes in the ovary and uterus during the human menstrual cycle m) outline the biological basis of contraceptive pills containing oestrogen and/or progesterone

15.2 Control and co-ordination in plants Plant co-ordination systems involve rapid responses as in the case of the Venus fly trap, but also complex interactions between plant growth regulators, such as auxin and gibberellin. Plants respond quite differently to different concentrations of plant growth regulators.	a) describe the rapid response of the Venus fly trap to stimulation of hairs on the lobes of modified leaves and explain how the closure of the trap is achieved b) explain the role of auxin in elongation growth by stimulating proton pumping to acidify cell walls c) describe the role of gibberellin in the germination of wheat or barley d) explain the role of gibberellin in stem elongation including the role of the dominant allele, *Le*, that codes for a functioning enzyme in the gibberellin synthesis pathway, and the recessive allele, *le*, that codes for a non-functional enzyme

Back to contents page

16 Inherited change

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

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
16.1 Passage of information from parent to offspring Diploid organisms contain pairs of homologous chromosomes. The behaviour of maternal and paternal chromosomes during meiosis generates much variation amongst individuals of the next generation.	a) explain what is meant by homologous pairs of chromosomes b) explain the meanings of the terms haploid and diploid and the need for a reduction division (meiosis) prior to fertilisation in sexual reproduction c) outline the role of meiosis in gametogenesis in humans and in the formation of pollen grains and embryo sacs in flowering plants d) describe, with the aid of photomicrographs and diagrams, the behaviour of chromosomes in plant and animal cells during meiosis, and the associated behaviour of the nuclear envelope, cell surface membrane and the spindle (names of the main stages are expected, but not the sub-divisions of prophase) e) explain how crossing over and random assortment of homologous chromosomes during meiosis and random fusion of gametes at fertilisation lead to genetic variation including the expression of rare, recessive alleles

16.2 The roles of genes in determining the phenotype Patterns of inheritance are explained by using genetic diagrams. The results of genetic crosses are analysed statistically using the chi-squared test.	a) explain the terms gene, locus, allele, dominant, recessive, codominant, linkage, test cross, F1 and F2, phenotype, genotype, homozygous and heterozygous b) use genetic diagrams to solve problems involving monohybrid and dihybrid crosses, including those involving autosomal linkage, sex linkage, codominance, multiple alleles and gene interactions (the term epistasis does not need to be used; knowledge of the expected ratio for various types of epistasis is not required. The focus is on problem solving) c) use genetic diagrams to solve problems involving test crosses d) 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) (see Mathematical requirements) e) explain that gene mutation occurs by substitution, deletion and insertion of base pairs in DNA and outline how such mutations may affect the phenotype
Studies of human genetic conditions have revealed the links between genes, enzymes and the phenotype.	f) outline the effects of mutant alleles on the phenotype in the following human conditions: albinism, sickle cell anaemia, haemophilia and Huntington's disease g) explain the relationship between genes, enzymes and phenotype with respect to the gene for tyrosinase that is involved with the production of melanin
16.3 Gene control Some genes are transcribed all the time to produce constitutive proteins; others are only 'switched on' when their protein products are required.	a) distinguish between structural and regulatory genes and between repressible and inducible enzymes b) explain genetic control of protein production in a prokaryote using the *lac* operon c) explain the function of transcription factors in gene expression in eukaryotes d) explain how gibberellin activates genes by causing the breakdown of DELLA protein repressors, which normally inhibit factors that promote transcription

Back to contents page

17 Selection and evolution

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

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
17.1 Variation The variation that exists within a species is categorised as continuous and discontinuous. The environment has considerable influence on the expression of features that show continuous (or quantitative) variation.	a) describe the differences between continuous and discontinuous variation and explain the genetic basis of continuous (many, additive genes control a characteristic) and discontinuous variation (one or few genes control a characteristic) (examples from 16.2f may be used to illustrate discontinuous variation; height and mass may be used as examples of continuous variation) b) explain, with examples, how the environment may affect the phenotype of plants and animals c) use the *t*-test to compare the variation of two different populations (see Mathematical requirements) d) explain why genetic variation is important in selection
17.2 Natural and artificial selection Populations of organisms have the potential to produce large numbers of offspring, yet their numbers remain fairly constant year after year. Humans use selective breeding (artificial selection) to improve features in ornamental plants, crop plants, domesticated animals and livestock.	a) explain that natural selection occurs as populations have the capacity to produce many offspring that compete for resources; in the 'struggle for existence' only the individuals that are best adapted survive to breed and pass on their alleles to the next generation b) explain, with examples, how environmental factors can act as stabilising, disruptive and directional forces of natural selection c) explain how selection, the founder effect and genetic drift may affect allele frequencies in populations d) use the Hardy–Weinberg principle to calculate allele, genotype and phenotype frequencies in populations and explain situations when this principle does not apply e) describe how selective breeding (artificial selection) has been used to improve the milk yield of dairy cattle f) outline the following examples of crop improvement by selective breeding: • the introduction of disease resistance to varieties of wheat and rice • the incorporation of mutant alleles for gibberellin synthesis into dwarf varieties so increasing yield by having a greater proportion of energy put into grain • inbreeding and hybridisation to produce vigorous, uniform varieties of maize

17.3 Evolution Isolating mechanisms can lead to the accumulation of different genetic information in populations, potentially leading to new species. Over prolonged periods of time, some species have remained virtually unchanged, others have changed significantly and many have become extinct.	a) state the general theory of evolution that organisms have changed over time b) discuss the molecular evidence that reveals similarities between closely related organisms with reference to mitochondrial DNA and protein sequence data c) explain how speciation may occur as a result of geographical separation (allopatric speciation), and ecological and behavioural separation (sympatric speciation) d) explain the role of pre-zygotic and post-zygotic isolating mechanisms in the evolution of new species e) explain why organisms become extinct, with reference to climate change, competition, habitat loss and killing by humans

Back to contents page

18 Biodiversity, classification and conservation

The biodiversity of the Earth is threatened by human activities and climate change. Classification systems attempt to put order on the chaos of all the organisms that exist on Earth. Field work is an important part of a biological education to appreciate this diversity and find out how to analyse it. There are opportunities in this section for candidates to observe different species in their locality and assess species distribution and abundance. Conserving biodiversity is a difficult task but is achieved by individuals, local groups, national and international organisations. Candidates should appreciate the threats to biodiversity and consider the steps taken in conservation, both locally and globally.

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
18.1 Biodiversity Biodiversity is much more than a list of all the species in a particular area.	a) define the terms species, ecosystem and niche b) explain that biodiversity is considered at three different levels: • variation in ecosystems or habitats • the number of species and their relative abundance • genetic variation within each species c) explain the importance of random sampling in determining the biodiversity of an area d) use suitable methods, such as frame quadrats, line transects, belt transects and mark-release-recapture, to assess the distribution and abundance of organisms in a local area e) use Spearman's rank correlation and Pearson's linear correlation to analyse the relationships between the distribution and abundance of species and abiotic or biotic factors f) use Simpson's Index of Diversity (D) to calculate the biodiversity of a habitat, using the formula $D = 1-\left(\Sigma\left(\frac{n}{N}\right)^2\right)$ and state the significance of different values of D
18.2 Classification Organisms studied locally may be used to show how hierarchical classification systems are organised.	a) describe the classification of species into the taxonomic hierarchy of domain, kingdom, phylum, class, order, family, genus and species b) outline the characteristic features of the three domains Archaea, Bacteria and Eukarya c) outline the characteristic features of the kingdoms Protoctista, Fungi, Plantae and Animalia d) explain why viruses are not included in the three domain classification and outline how they are classified, limited to type of nucleic acid (RNA or DNA) and whether these are single stranded or double stranded

18.3 Conservation Maintaining biodiversity is important for many reasons. Actions to maintain biodiversity must be taken at local, national and global levels. It is important to conserve ecosystems as well as individual species.	a) discuss the threats to the biodiversity of aquatic and terrestrial ecosystems (see 18.1b) b) discuss the reasons for the need to maintain biodiversity c) discuss methods of protecting endangered species, including the roles of zoos, botanic gardens, conserved areas (national parks and marine parks), 'frozen zoos' and seed banks d) discuss methods of assisted reproduction, including IVF, embryo transfer and surrogacy, used in the conservation of endangered mammals e) discuss the use of culling and contraceptive methods to prevent overpopulation of protected and non-protected species f) use examples to explain the reasons for controlling alien species g) discuss the roles of non-governmental organisations, such as the World Wide Fund for Nature (WWF) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), in local and global conservation h) outline how degraded habitats may be restored with reference to local or regional examples

Back to contents page

19 Genetic technology

The discovery of the structure of DNA by Watson and Crick in the early 1950s and discoveries since have led to many applications of gene technology in areas of medicine, agriculture and forensic science. This section relies heavily on prior knowledge of DNA structure and protein synthesis studied in the section on Nucleic acids and protein synthesis. Where possible, candidates should carry out practical work using electrophoresis, either with DNA or specially prepared dyes used to represent DNA or proteins.

Candidates will be expected to use the knowledge gained in this section to solve problems in familiar and unfamiliar contexts.

	Learning outcomes Candidates should be able to:
19.1 Principles of genetic technology Genetic engineering involves the manipulation of naturally occurring processes and enzymes. Genome sequencing gives information about the location of genes and provides evidence for the evolutionary links between organisms.	a) define the term recombinant DNA b) explain that genetic engineering involves the extraction of genes from one organism, or the synthesis of genes, in order to place them in another organism (of the same or another species) such that the receiving organism expresses the gene product c) describe the principles of the polymerase chain reaction (PCR) to clone and amplify DNA (the role of *Taq* polymerase should be emphasised) d) describe and explain how gel electrophoresis is used to analyse proteins and nucleic acids, and to distinguish between the alleles of a gene (limited to the separation of polypeptides and the separation of DNA fragments cut with restriction endonucleases) e) describe the properties of plasmids that allow them to be used in gene cloning f) explain why promoters and other control sequences may have to be transferred as well as the desired gene g) explain the use of genes for fluorescent or easily stained substances as markers in gene technology h) explain the roles of restriction endonucleases, reverse transcriptase and ligases in genetic engineering i) explain, in outline, how microarrays are used in the analysis of genomes and in detecting mRNA in studies of gene expression

19.2 Genetic technology applied to medicine	a) define the term bioinformatics b) outline the role of bioinformatics following the sequencing of genomes, such as those of humans and parasites, e.g. *Plasmodium* (details of methods of DNA sequencing are not required) c) explain the advantages of producing human proteins by recombinant DNA techniques (reference should be made to some suitable examples, such as insulin, factor VIII for the treatment of haemophilia and adenosine deaminase for treating severe combined immunodeficiency (SCID)) d) outline the advantages of screening for genetic conditions (reference may be made to tests for specific genes such as those for breast cancer, *BRCA1* and *BRCA2*, and genes for haemophilia, sickle cell anaemia, Huntington's disease and cystic fibrosis) e) outline how genetic diseases can be treated with gene therapy and discuss the challenges in choosing appropriate vectors, such as viruses, liposomes and naked DNA (reference may be made to SCID, inherited eye diseases and cystic fibrosis) f) discuss the social and ethical considerations of using gene testing and gene therapy in medicine (reference should be made to genetic conditions for which treatments exist and where none exist, also to IVF, embryo biopsy and preselection and to therapeutic abortions) g) outline the use of PCR and DNA testing in forensic medicine and criminal investigations
19.3 Genetically modified organisms in agriculture The ability to manipulate genes has many potential benefits in agriculture, but the implications of releasing genetically modified organisms (GMOs) into the environment are subject to much public debate in some countries.	a) explain the significance of genetic engineering in improving the quality and yield of crop plants and livestock in solving the demand for food in the world, e.g. Bt maize, vitamin A enhanced rice (Golden rice™) and GM salmon b) outline the way in which the production of crops such as maize, cotton, tobacco and oil seed rape may be increased by using varieties that are genetically modified for herbicide resistance and insect resistance c) discuss the ethical and social implications of using genetically modified organisms (GMOs) in food production

Back to contents page

4. Practical assessment

4.1 Introduction

Teachers should ensure that learners practise experimental skills throughout their course of study. As a guide, learners 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 learners do during their course should aim to:

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

Candidates' experimental skills will be assessed in Paper 3 and Paper 5. In each of these papers, the questions may be based on biology not included in the syllabus content, but candidates will be assessed on their practical skills rather than their knowledge of theory. Where appropriate, candidates will be told exactly what to do and how to do it.

Examples of unfamiliar contexts might include:

- following instructions to set up and use unfamiliar equipment
- making microscopic observations, drawings and magnification calculations from unfamiliar structures or specimens
- following instructions to use unfamiliar biochemical procedures.

4.2 Paper 3

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 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 Centres 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 Centres may wish to enter all of their candidates for the same paper. Each of these papers will be timetabled on a different day.

Paper 3 will be a timetabled, laboratory-based practical paper focusing on the following investigational skills:

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

Each paper:

- has two or more questions
- requires candidates to carry out an investigation or investigations. They may be asked to:
  - make decisions on techniques
  - collect quantitative or qualitative data
  - present the data or observations as tables, charts, graphs and other appropriate means
  - make appropriate analyses, including making calculations
  - make conclusions
  - suggest improvements to the procedure or modifications for extending the investigation
- requires candidates to carry out one activity using a light microscope. They may be asked to:
  - prepare slides
  - make observations of specimens
  - present their observations appropriately
  - make appropriate analyses, including measurements and calculations
  - make deductions and conclusions from the observations
- requires the Centre to provide microscopes for half of the candidates at a time (see Section 4.2.4 for microscope specifications) so half the candidates should start on the investigation while the others start with access to the light microscope, then after one hour the candidates should have access to the other question
- includes questions set in different areas of AS Level Biology, and may include material from unfamiliar contexts.

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

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

Back to contents page

4.2.1 Mark scheme for Paper 3

Paper 3 is marked using the generic mark scheme shown below. The expectations for each mark category are listed in the sections that follow.

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

4.2.2 Expectations for each mark category (Paper 3)

Investigations

Manipulation of apparatus, measurement and observation (MMO)

These marks are awarded for two strands of skills:

- Making decisions about measurements or observations
- Successfully collecting data and observations.

Making decisions about measurements or observations

Within an investigation, candidates should use the skills, knowledge and understanding of the AS Level Biology syllabus to:

- Identify the independent and dependent variable
- Decide how the independent variable should be changed within a suitable range to provide accurate results. Candidates should:
  - decide the range to use for an independent variable and decide how to change its values, including:
    - concentration (using simple or serial dilution)
    - temperature (selected from above freezing to 100 °C)
    - pH (using buffers)
    - moving air (using a fan)
    - humidity (using a plastic bag or calcium hydroxide)
  - decide the number of values at which measurements are recorded (a minimum of 5 measurements, replicates or more measurements around a specific value)
  - decide on the spacing of the values, for example, if more measurements are needed around a specific variable
  - decide intervals including concentration, temperature or pH
  - decide the number of replicates at each value
  - decide how to identify the presence of a biological molecule and estimate its quantity by standardising the appropriate test
- Describe an appropriate control which removes the effect of the independent variable (including replacing a solution with the same volume of water or denaturing an enzyme by boiling)
- Decide which variables to standardise because they may change the results if the variable changes during the investigation and decide how to standardise each variable to provide accurate results. These include:
  - volume (must be suitable for apparatus)
  - concentration
  - temperature
  - pH
  - biological material (for example same species; age; storage conditions; time of year; mass)
  - humidity (using a plastic bag or calcium hydroxide)
  - apparatus

Back to contents page

- Decide and describe how the dependent variable has been measured to obtain accurate and precise results

  Candidates should:

  – Use a variety of techniques to measure dependent variables, including release of gases; absorption of gases; change in colour (using an indicator for change in pH); time (to a colour change when testing for biological molecules); counting (e.g. cells showing degrees of plasmolysis)

  – Decide on the frequency of measurement (e.g. measurements to determine the initial rate of a reaction should be taken as quickly as possible after the reaction starts)

  – Decide how long to allow for taking measurements to determine a rate of reaction, time for a colour change or time for a reaction to reach an end-point

  – Decide whether to repeat or replicate readings in order to identify anomalous results or to provide a more accurate estimate

  – Decide an appropriate number of significant figures for measurements or clear descriptions of observations

  – Decide how to measure an area using a grid, counting those areas covering half or more of a grid square as one whole square and not counting those areas less than half a square.

Successfully collecting data and observations

Within an investigation, candidates should be able to:

- Follow instructions or diagrams using a range of techniques to collect results
- Assess the risk of a procedure as low, medium or high using the hazards of solutions and reagents and the procedure
- Take readings using a range of apparatus to obtain accurate data or observations with the expected pattern of results:
  – Quantitative results
    - measure all results to an appropriate number of significant figures, using a range of apparatus which includes temperature changes with time; distance with time; time for a colour change; angle of bend; volumes of gases or solutions
    - measure using counting: tally counts, e.g. to count bubbles in a minute; grids for surface area; numbers of cells
  – Qualitative results from observations of colour changes, using clear descriptions, for example:
    - 'blue' or 'orange' or 'purple' with use of 'pale' or 'dark' for fine discrimination
    - a number scale 1 to 5 for intensity of colour with a key
    - a suitable symbol such as + or ✓ to represent cloudiness or intensity of colour (a key should always be given).

Presentation of Data and Observations (PDO)

These marks are awarded for three strands of skills:

- Recording data and observations
- Displaying calculations and reasoning
- Layout of data or observations.

Recording data and observations

Within an investigation, candidates should be able to:

- Record only the raw data (unprocessed results) as quantitative data and qualitative observations in a fully ruled table with no units in the body of the table

Candidates should:

  - prepare a table with a heading for the independent variable in the left column or top row with appropriate units and a heading for dependent variable with units
  - record quantitative data to the same number of significant figures dependent on the measuring instrument used
  - record qualitative observations using clear descriptions
- Record calculated values (processed results) selecting whether to include these with raw results or in a separate table.

Displaying calculations and reasoning

Within an investigation, candidates should be able to:

- Show calculations clearly showing all the steps in the calculation and their reasoning
- Use the correct number of significant figures for calculated quantities. This should be the same number of significant figures as (or one more than) the measured quantity of least accuracy.

Layout of data or observations

Within an investigation, candidates should be able to:

- Select whether data should be shown as a graph or chart and then present the graph or chart clearly and accurately

Candidates should draw a graph or chart with:

  - axes with the independent variable on the *x*-axis, clearly labelled (to match the relevant table heading) with units where appropriate and the dependent variable (to match the relevant table heading) on the *y*-axis labelled with units, where appropriate
  - a scale where both axes should use most or all of the grid available and allow the graph to be read easily to half a 2 mm square, such as 1, 2, or 5 units to a maximum of 20 mm
  - all points plotted accurately. Points should be drawn with a sharp pencil, as a small cross or a small dot in a circle. The intersection of the cross or centre of the dot should be exactly on the required point
  - for a graph (based on data provided) the plotted points should be connected with a clear, sharp and unbroken
    - line of best fit
    - smooth curve
    - set of ruled straight lines to join the points

  The graph should not be extrapolated unless this can be assumed from the data
  - all bars should be plotted accurately with the horizontal lines as a thin ruled line
  - for a chart (based on the data provided) bars should be separated for discrete or categorical data and joined for continuous data. Lines should be clear, sharp and unbroken and bars unshaded and clearly labelled.

Back to contents page

Analysis (interpretation of data or observations), conclusions and evaluation (ACE)

These marks are awarded for three strands of skills:

- Interpreting data or observations and identifying sources of error
- Drawing conclusions
- Suggesting improvements or modifications to extend the investigation.

Interpreting data or observations and identifying sources of error

Within an investigation, candidates should be able to:

- Calculate the correct answer with the correct number of significant figures using quantitative results or data provided. This includes calculating mean, percentage, change in mass or length, percentage change (gain or loss), and finding the rate of reaction using data including 1/time or using the gradient of a line graph
- Find an unknown value by using co-ordinates or intercepts with axes on a graph or extrapolation where the data allows
- Estimate the concentration of unknown solutions from qualitative results
- Identify the contents of unknown solutions using biological molecule tests
- Identify anomalous results and remove them before beginning calculations, e.g. when calculating means
- Describe patterns and trends using the data provided in tables and graphs
- Identify systematic or random errors from using apparatus in an investigation and understand that systematic errors do not affect the trend in results whereas a random error, for example, due to variability of biological material, may affect the trend and accuracy
- Identify the significant sources of error in a particular investigation as any variable that may change during the recording of results so making the results less accurate

  Note: Contamination is not considered a significant source of error since washing correctly should remove contamination.
- Estimate quantitatively, by calculating the actual error or percentage error (where a particular measurement is given) to evaluate the uncertainty in quantitative measurements and evaluate the confidence in the accuracy of results (how close they are to the true value)
- Evaluate the effect of the standardisation of variables on the general trend or pattern and therefore the confidence with which conclusions might be made.

Drawing conclusions

Within an investigation, candidates should be able to:

- Make conclusions:
  - to predict a trend from provided information or results
  - from the patterns and trends in data
  - on whether investigational data support a given hypothesis
  - from results, including estimating an unknown concentration using known concentrations
- Make scientific explanations, using skills, knowledge and understanding of the AS Level Biology syllabus, of:
  - data collected
  - observations
  - calculated values
  - described conclusions
  - information provided in unfamiliar contexts.

Suggesting improvements or modifications to extend an investigation

Within an investigation, candidates should be able to:

- Suggest improvements to a procedure that will increase the accuracy of the procedure for the investigation or accuracy of the observations to include how to:
  - standardise relevant variables
  - use a measurement method for the dependent variable which is more accurate
  - collect more data by taking replicate measurements to obtain a mean
- Suggest how to modify or extend the investigation to answer a new question or change the independent variable and describe such modifications clearly in words or diagrams, including how to:
  - change a different independent variable
  - standardise all other variables including a previously used independent variable
  - use an improved method to obtain accurate and precise results for the dependent variable.

Back to contents page

Light microscope and photomicrographs

Manipulation, measurement and observation (MMO)

These marks are awarded for two strands of skills:

- Making decisions about measurements or observations
- Successfully collecting data and observations.

Making decisions about measurements or observations

This strand requires the use of a light microscope and photomicrographs.

Candidates should decide how to:

- Set up a light microscope to view and observe specimens, in order to make either plan diagrams to show tissue distribution or to draw cells to include only the observable features
- Draw the distribution of different tissues in plant and animal specimens and label the drawings appropriately
- Correctly identify cells and label the structures of cells
- Stain and make a slide of cells
- Calibrate an eyepiece graticule using a stage micrometer
- Obtain actual sizes of tissues or cells using a calibrated eyepiece graticule, by measuring the tissues or cells to obtain a mean measurement, using the correct units for microscopy (μm)
- Estimate the number of cells or cell organelles in a whole slide or field of view using a sample or using a grid.

Successfully collecting data and observations

This strand requires the use of a light microscope and prepared slides and photomicrographs.

Candidates should be able to collect:

- Observations by drawing the distribution of tissues in a specimen, as plan diagrams, with no cells drawn and correct proportions of layers of tissues
- Observations by drawing the observable features of cells in a specimen showing:
  - the correct shapes
  - the thicknesses of cell walls (which are drawn with two lines with a third line between adjacent cells)
  - the relative sizes (using (uncalibrated) eyepiece graticule scale)
  - observable cell contents only
- Correct measurements of tissue layers or cells, including:
  - using a calibrated eyepiece graticule
  - using scale bars
  - appropriate magnification
- Correct observations from specimens, including numbers of cells or cell organelles, using sampling or a grid or tally counts or numbers of stained to non-stained cells
- Similarities and differences between two specimens using only their observable features.

Presentation of Data and Observations (PDO):

These marks are awarded for three strands of skills:

- Recording data and observations
- Displaying calculations and reasoning
- Data or observations layout.

Recording data and observations

This strand uses a light microscope, prepared slides and photomicrographs.

Candidates should be able to:

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

Displaying calculations and reasoning

This strand uses a light microscope, prepared slides and photomicrographs.

Candidates should be able to show calculations, clearly showing all the steps in the calculation and their reasoning, including:

- The calibration of the eyepiece graticule
- The actual size (using an eyepiece graticule or magnification scale bar)
- The linear magnification
- The total number, e.g. stomata per unit of area (for example field of view)
- The mean measurement of length or number
- Determining the simplest ratio (expressed as larger whole number to smaller whole number, to the lowest common denominator)
- Using the correct number of significant figures for calculated quantities.

Data or observations layout

This strand uses a light microscope, prepared slides and photomicrographs.

Candidates should be able to:

- Make drawings, using a sharp pencil, to give finely drawn lines. Drawings should:
  - have clear, sharp, unbroken lines
  - be unshaded
  - use most of the available space to show all the features observed in the specimen
- Organise comparative observations, showing differences and/or similarities, of specimens of biological material.

Analysis (interpretation of data or observations), conclusions and evaluation (ACE)

These marks are awarded for three strands of skills:

- Interpreting data or observations and identifying sources of error
- Drawing conclusions
- Suggesting improvements or modifications to extend investigation.

Back to contents page

Interpreting data or observations and identifying sources of error

These activities use results from observations using a light microscope, prepared slides and photomicrographs.

Candidates should be able to:

- Calculate the correct answer with the correct number of significant figures, using quantitative results or provided data including:
  - the calibration of the eyepiece graticule scale
  - the actual size of a specimen (using a calibrated eyepiece graticule, a magnification or a scale bar)
  - the magnification of a specimen
  - the number in a field of view, e.g. number of stomata per unit of area
- Compare observable features of specimens of biological material including similarities and differences between microscopic slides of specimens and photomicrographs of specimens.

Drawing conclusions

This strand uses observations using a light microscope, prepared slides and photomicrographs.

Candidates should be able to:

- Using the skills, knowledge and understanding acquired from the AS Level Biology syllabus make scientific explanations of:
  - observations of specimens
  - calculated values
  - how a specimen is adapted for a particular habitat.

Suggesting improvements or modifications to extend an investigation

These activities use results of observations using a light microscope, prepared slides and photomicrographs.

Candidates should be able to:

- Suggest improvements to a procedure that will increase the accuracy of the observations that can be made, to include how to:
  - use a measurement method which uses smaller intervals to improve accuracy and precision
  - collect more data by taking replicate results to obtain a mean.

4.2.3 Administration of Paper 3

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

Details of specific requirements for apparatus and materials for a particular examination are given in the Confidential Instructions which are sent to Centres, several weeks prior to the examination. Centres should contact 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 describe information required by the Examiners. This will include a set of results for the experiments, which the Supervisor should obtain out of sight of the candidates. A Supervisor's Report Form is included in the Confidential Instructions. Centres must complete this form and enclose a copy in each envelope of scripts. If any assistance is given to candidates, the Supervisor's Report Form must include full details of this assistance. The marking process may be delayed and candidates may be disadvantaged if the Supervisor's Report Form or sample results are missing or do not contain the information required.

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 email (info@cie.org.uk) or fax (+44 1223 553558) or telephone (+44 1223 553554).

4.2.4 Apparatus that is used regularly for Paper 3

The apparatus required for Paper 3 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.

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.

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 one hour.

Back to contents page

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 Paper 3. 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)
- 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*

Back to contents page

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 contain reducing sugars.)
- Glucose
- Starch
- Albumen (or egg white)
- [**C**] – Potassium hydroxide
- [**C**] – Sodium hydroxide
- Sodium chloride
- [**H**] – Dilute hydrochloric acid
- Hydrogencarbonate indicator (with air pump to equilibrate to atmospheric carbon dioxide)
- Sodium bicarbonate/sodium hydrogencarbonate
- [**H**] – Limewater
- [**H**] – Hydrogen peroxide
- Distilled/deionised water
- Universal Indicator paper and chart
- Litmus solution and red and blue litmus paper
- Eosin/red ink
- [**F**] – Thymolphthalein indicator
- [**H**] – Bromothymol blue
- [**H**] – Methylene blue
- Vaseline/petroleum jelly (or similar)
- DCPIP (dichlorophenol-indophenol)
- Ascorbic acid (vitamin C)
- Diastix for testing glucose concentration
- Albustix or another appropriate test strip for testing protein
- [**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, toluidine blue
- [**H**] – Feulgen stain (Schiff's reagent)
- Nutrient broth, nutrient agar and technical agar (Note: technical agar is suitable for making agar blocks)
- Appropriate disinfectants
- Solvents for chromatography of chloroplast pigments
- Aquatic plants for photosynthesis investigations, e.g. *Elodea*, *Cabomba*

Apparatus for field work:

- 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
- Frame quadrats, open or gridded
- Tape measures

Slides:

For 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 A Level

- Meiosis
- TS anther, TS ovule
- Pollen
- VS maize fruit
- TS kidney
- TS spinal cord
- 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*)

Back to contents page

4.2.5 Safety in the laboratory

Responsibility for safety matters rests with Centres. Attention is drawn to the following UK associations, publications and regulations.

Associations

CLEAPSS is an advisory service providing support in practical science and technology.
www.cleapss.org.uk

The Association for Science Education promotes excellence in science teaching and learning.
www.ase.org.uk

Publications

Safeguards in the School Laboratory, ASE, 11th edition, 2006
Topics in Safety, ASE, 3rd edition, 2001
CLEAPSS Laboratory Handbook, updated annually (available to CLEAPSS members only)
CLEAPSS Hazcards, updated annually (available to CLEAPSS members only)
Hazardous Chemicals, an interactive manual for science education, SSERC, 2002 (CD)

UK Regulations

Control of Substances Hazardous to Health Regulations (COSHH) 2002
www.legislation.gov.uk/uksi/2002/2677/contents/made

A brief guide may be found at:
www.hse.gov.uk/pubns/indg136.pdf

European Regulations

The European Chemicals Agency, ECHA, publishes a 'candidate list' of chemicals that are scheduled to require authorisation under EU chemicals legislation and are therefore unsuitable for use in schools:
www.echa.europa.eu/web/guest/candidate-list-table

4.3 Paper 5

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

- planning
- analysis of experimental data
- evaluation of experimental results and conclusions.

This examination will not require laboratory facilities. However, **Centres should note that candidates cannot be prepared properly for this paper without carrying out 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 practical skills as part of the AS Level course and are able to apply these skills in more complex investigations and to interpret data in a variety of ways.

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

Paper 5 will include two or more questions and will require:

- answers using extended, structured writing, and use of appropriate diagrams and tables to illustrate answers
- candidates to design an experimental method for a given problem, for which they may be asked to use given information or a specific piece of apparatus
- candidates to be able to express a prediction as a written hypothesis linking independent and dependent variables, or as a graph showing the expected result
- candidates to make analyses, evaluations and conclusions from given experimental data, presented as tables, graphs or written statements
- candidates to identify appropriate mathematical or statistical methods to process experimental data
- answers to questions on parts of the syllabus that cannot easily be investigated experimentally in school laboratories, either because of the cost of equipment (such as electrophoresis) or because the samples and materials are not easily available (such as living individuals of rare species, or probes for identifying mutant alleles).

Back to contents page

4.3.1 Mark scheme for Paper 5

Paper 5 is marked using the generic mark scheme shown below. The expectations for each mark category are listed in the sections that follow.

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
		Conclusions	3 marks

4.3.2 Expectations for each mark category (Paper 5)

Planning

For planning, candidates use a given scenario and background information to identify key variables and develop a procedure to test a hypothesis or prediction.

These marks are awarded for two strands of skills:

- Defining the problem
- Methods.

Defining the problem

From a given scenario candidates should be able to:

- Express the aim of an experiment or investigation as a prediction or hypothesis, expressed in words or in the form of a sketch graph showing the expected result. The hypothesis 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
- 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, for example, the effect of light intensity on the rate of photosynthesis at two or more concentrations of carbon dioxide
- Identify the dependent variable as the factor that is **measured directly** during the experiment or investigation. The dependent variable may respond to the changes in the independent variable
  - in some cases candidates may be required to identify that there is 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
  - For investigations that have a hypothesis or aim stated in terms of a variable that cannot be measured directly, candidates will be required to identify:
    - a feature of the investigation that can be measured directly, e.g. rate of transpiration
    - a measurable aspect of transpiration that can be used, such as mass loss, distance moved by water in a capillary in a specified time

- Identify which **key** variables must be standardised in order to test a hypothesis effectively. Only variables that are appropriate for the given scenario and likely to have some effect on the investigation are expected, for example, time of investigation, but not those likely to have a very small effect, for example, using the same test-tube.

Methods

From a given scenario, candidates will be assessed on their ability to describe a method that could be used by another person without any further information to collect the necessary data without difficulty.

When describing the method, candidates should be able to:

- Use the information provided in the scenario to describe how to vary the independent variable, and the ways in which they would make sure they had measured its values accurately
- Describe how to measure the dependent variable. This could include using either, as appropriate, the apparatus or materials specified in the scenario or measuring instruments chosen to measure the correct quantity to a suitable number of significant figures. This may include the use of monitoring devices and computer technology to record changes
- Describe how to standardise each of the other key variables using appropriate methods for the apparatus and nature of the investigation, e.g. using a dropping pipette is not appropriate to measure small volumes of a solution
- Describe, where appropriate, suitable volumes and concentrations of reagents, and explain how different concentrations would be prepared

  Concentrations may be specified:

  – in %(w/v), 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

  Dilutions may be made by:

  – serial dilution, by making the same dilution step again and again, 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
  – 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
- Describe, if appropriate, 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 two types:

  – where all factors are kept identical to the experimental set up except that the value of the independent variable is zero, for example when water is used instead of a test solution
  – where the control is to confirm that, for example, it is an organism that is causing a particular effect, by leaving out or replacing the organism with non-living material, e.g. sterile glass beads instead of an insect in a respirometer
- Describe, in a logical sequence, the steps involved in the procedure including how to use the apparatus to collect results
- Describe how to ensure the quality of results by considering any anomalous results and the spread of results by inspection and then by using standard deviation, standard error or 95% confidence interval (CI). Results are precise if they are repeatable by the same candidate and reproducible by others
- Describe how to ensure the validity of the results by considering both the success at measuring the intended dependent variable and the precision required

Back to contents page

- Include 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 the precautions that would need to be taken to minimise risks where possible. These precautions should be specifically related to the risks they have identified, for example soda lime used to absorb carbon dioxide is corrosive and poses a particular risk if it comes in to contact with the skin and cornea, so wearing gloves and eye protection would be an appropriate precaution.

Analysis, conclusions and evaluation

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

These marks are awarded for three strands of skills:

- Dealing with data
- Evaluation
- Conclusions.

Dealing with data

Knowledge of the Mathematical requirements in Section 5.1 of the syllabus is expected.

From provided data, candidates should be able to:

- Decide which calculations are necessary in order to draw conclusions, including considering the use of:
  - error levels
  - confidence limits
  - statistical tests
- Use tables and graphs to identify the key points in quantitative data, including the variability of data
- Sketch or draw suitable graphs displaying the independent variable on the *x*-axis and the dependent variable on the *y*-axis, including confidence limit error bars, calculated using standard error
- Choose appropriate calculations to simplify or explain data
- Carry out calculations in order to simplify or compare data

  These calculations may include:
  - percentage and percentage gain or loss
  - rate of change
  - species diversity index
  - estimation of population size
- Use values of standard deviation or standard error, or graphs with standard error bars, to determine whether differences in mean values are likely to be statistically significant
- Choose statistical tests appropriate to the type of data collected and justify use of these tests
- State a null hypothesis for a statistical test
- Apply statistical methods in order to assess variability in data. These methods may include:
  - Use of descriptive statistics statistical tests to assess the variability of data or the statistical differences between samples, including *t*-test, chi-squared test, Pearson's linear correlation and Spearman's rank correlation
  - Calculate the degrees of freedom for a statistical test
  - Use a probability table to determine the significance of a calculated value for the *t*-test and the chi-squared test
- Recognise the different types of variable and the different types of data presented.

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, where values that can be placed in an order or rank and the interval between them may not be equal, e.g. the order in which test-tubes containing starch and iodine become colourless after adding amylase
Quantitative	continuous, which can have any value within a specific range and can be expressed as a whole number, fraction or a decimal. It can be counted, ordered and measured, e.g. body mass, leaf length

Evaluation

Using given data, candidates should be able to:

- Identify anomalous values in a table or graph of data and suggest how to deal with anomalies. Strategies for dealing with such anomalies include:
  - repeating the experiment until consistent results are obtained
  - leaving out the affected data
- Suggest possible explanations for anomalous readings. Where investigations use familiar contexts that have been explored during the course, candidates should be able to suggest possible causes for such anomalies
- Assess whether the provided data has been replicated sufficiently and describe whether the range of measured data was appropriate and the intervals between data was appropriate
- Explain why replicating data is important and the practical limits on replication
- Identify instances where:
  - More measurements need to be taken with an increased or decreased value of the independent variable in order to give a complete range of data values
  - There are gaps in the range of the independent variable which reduce the information the investigation can give
- Assess whether the method of measuring is appropriate for the dependent variable, for example, 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
- Assess the extent to which selected variables have been effectively controlled, using given information, for example, whether the temperature recorded was the same for each of a number of samples
- Use these evaluations and any given information to make informed judgements about:
  - how much confidence can be put in any conclusions
  - the validity of the investigation
  - how much the data can be trusted for testing the hypothesis.

Back to contents page

Conclusions

Conclusions are expected to include detailed scientific explanations and must refer to knowledge and understanding gained in the AS Level and A level syllabus.

From provided data, candidates should be able to:

- Make conclusions that:
  - include key points of the raw data, processed data, graphical representations and statistical test results
  - quote relevant figures from raw or processed data where appropriate
- Decide whether a given hypothesis is supported by experimental data, considering:
  - whether the hypothesis is supported by experimental data in particular, has been fully supported or not supported
  - strengths and weaknesses of any support for or against the hypothesis
- Give detailed scientific explanations of the data and of their conclusions, applying the skills, knowledge and understanding that they have gained from their studies
- Make further predictions and hypotheses based on their conclusions
- Make relevant suggestions about how an investigation could be improved to increase confidence in the results. These could include:
  - alternative methods of measuring the dependent variable, for example, using a biosensor to measure glucose concentration instead of Benedict's solution
  - narrowing the range and decreasing the intervals between concentrations of a solution to obtain a more accurate result.

5. General syllabus requirements and information

5.1 Mathematical requirements

At AS Level and A Level

Candidates should be able to:

- recognise and use expressions in decimal and standard form
- use a calculator for addition, subtraction, multiplication and division, finding the arithmetical mean and to find and use x, x^2, $\frac{1}{x}$, $\log_{10}x$ and $\sqrt{x}$
- understand and use the symbols <, >, Δ, $\approx$, /, ∞, Σ
- understand and use the prefixes: giga (G), mega (M), kilo (k), milli (m), micro (μ), and nano (n)
- calculate magnifications and actual sizes
- take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified
- make estimations of the results of calculations (without using a calculator)
- use a spreadsheet program for collating, analysing and presenting data
- recognise and use ratios
- calculate percentages and percentage changes
- express errors in experimental work as percentage errors
- calculate areas of right-angled and isosceles triangles, circumferences and areas of circles, areas and volumes of cylinders, rectangles and rectangular blocks
- translate information between graphical, numerical, and algebraic forms
- construct and interpret frequency distributions and diagrams, such as pie charts, bar charts and histograms
- understand when information should be presented in the form of a bar chart, histogram or line graph
- select appropriate variables and scales for graph plotting using standard 2 mm square graph paper
- recognise when it is appropriate to join the points on a graph with straight ruled lines and when it is appropriate to use a line (straight or curved) of best fit
- calculate the rate of change from a line on a graph
- draw and use the slope of a tangent to a curve as a means to obtain the rate of change.

Back to contents page

At A Level only

Candidates should be able to:

- have sufficient understanding of probability to understand genetic ratios
- understand the principles of sampling as applied to biological situations and data
- understand the importance of chance when interpreting data
- use the Petersen or Lincoln index to calculate an estimate of population size using mark-release-recapture data and the formula:

  $$N = \frac{n_1 \times n_2}{m_2}$$

  N = population estimate

  n_1 = number of marked individuals released

  n_2 = number of individuals (both marked and unmarked) captured

  m_2 = number of marked individuals recaptured

- calculate Simpson's Index of Diversity (D) using the formula:

  $$D = 1 - \left(\Sigma\left(\frac{n}{N}\right)^2\right)$$

  n = number of individuals of each type present in the sample (types may be species and/or higher taxa such as genera, families, etc.)

  N = the total number of all individuals of all types
- calculate standard deviation and standard error
- understand the benefits of using standard error and 95% confidence intervals (95%CI) to make statements about data and to use as error bars on graphs
- understand the difference between correlation and causation; use Spearman's rank correlation and Pearson's linear correlation to test for correlation
- use the χ^2 test and the *t*-test
- use a spreadsheet program for analysing and presenting data, making calculations and carrying out statistical tests.

5.1.1 Notes on the use of statistics in biology

Candidates should know the distinction between *descriptive statistics* and *statistical tests*. They should also appreciate the requirement to choose appropriate statistical methods *before* planning an investigation in which they will either collect primary data or analyse secondary data. Candidates should have an understanding of the different types of variable and also the different types of data they may collect or be asked to analyse.

Descriptive statistics

For quantitative data, candidates should understand the difference between a *normal distribution* and a distribution that is non-normal. Candidates should know appropriate descriptive statistical methods to simplify their data. They should be able to use a calculator and/or spreadsheet program to find the mean, median, mode, total range, interquartile range, standard deviation, standard error and the 95% Confidence Interval (CI). Standard error (SE) and 95%CI are useful for expressing the reliability of an estimate of the mean and for putting error bars on graphs. Candidates should understand how to apply these methods and explain their significance for their own data and any given data. The 95%CI is determined as the mean ±2 × SE.

Statistical tests

Candidates should know when it is appropriate to use a statistical test. They should be able to use statistical tests to test for an association and know when to test for the significance of differences between samples.

The **chi-squared** (χ^2) test is used to test the difference between observed and expected frequencies of nominal data. The chi-squared test allows the evaluation of the results of breeding experiments and some forms of ecological sampling. Chi-squared tests will only be expected on one row of data.

The ***t*-test** is of value in much of biology to test for the significance of differences between two samples each with continuous data. This test should be used if:

- continuous data has been collected
- the data is from a population that is normally distributed
- standard deviations are approximately the same
- the two samples have fewer than 30 values each.

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

- continuous data has been collected
- a scatter diagram indicates the possibility of a linear relationship
- the data is from a population that is normally distributed
- the number of paired observations should ideally be 10 or more, but the test can be used if there are at least 5.

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

- data points within samples are independent of each other
- ordinal data has been collected or the data that has been collected can be converted to an ordinal scale using ranking
- a scatter diagram indicates the possibility of an increasing or a decreasing relationship
- the number of paired observations should ideally be between 10 and 30 in total. The test can be used if there are more than 5
- all individuals must be selected at random from a population; each individual must have an equal chance of being selected.

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

Candidates should also know that a correlation does not necessarily imply a causative relationship.

These statistical methods are dealt with fully in many books and websites 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, standard errors and 95% confidence intervals (which they may use for error bars on graphs)
- to use the *t*-test to find out if there is a significant difference between the means of two small unpaired samples

Back to contents page

- to use the chi-squared test to analyse data from genetics or ecology
- to use Spearman's rank correlation to test for a correlation between two sets of non-normal data
- to use Pearson's linear correlation to test for a correlation between two sets of normally distributed data.

Candidates will be given access to the equations, the meanings of the symbols, appropriate tables or the appropriate critical values. In both the *t*-test and the chi-squared test they should be able to calculate the number of degrees of freedom without any reminders.

They should appreciate levels of significance and use calculated (or given) values of t, χ^2, r and r_s to make appropriate conclusions.

Candidates are **not** expected to remember the following equations and symbols.

standard deviation	$s = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$
t-test	$t = \frac{\lvert\bar{x}_1 - \bar{x}_2\rvert}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$ $\quad v = n_1 + n_2 - 2$
χ^2 test	$\chi^2 = \sum\frac{(O-E)^2}{E}$ $\quad v = c - 1$
standard error	$S_M = \frac{s}{\sqrt{n}}$
Spearman's rank correlation	$r_s = 1 - \left(\frac{6 \times \sum D^2}{n^3 - n}\right)$ n is the number of pairs of items in the sample and D is the difference between each pair of ranked measurements
Pearson's linear correlation	$r = \frac{\sum xy - n\bar{x}\bar{y}}{n\, s_x\, s_y}$

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, y = observations

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 $s_n(\sigma)$ and s_{n-1} (σ_{n-1}).

Papers 4 and 5 may include questions involving the use of descriptive statistics and the statistical tests stated in the syllabus. Candidates will **not** be expected to carry out all the steps in these calculations during an examination, but they may be given partly completed calculations to finish.

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

5.2 Glossary of command words

The glossary should prove helpful to candidates as a guide, although it is not exhaustive and it has been deliberately kept brief. 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 indicates 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. If a specific number of points is requested, this number should not be exceeded.
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*: give a critical account of the points involved in the topic.
8. *Outline*: the answer should be brief, restricted to giving essentials, without supporting details.
9. *Predict*: 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*: 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*: 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*: 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*: 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.

Back to contents page

15. *Determine*: often implies that the quantity in question cannot be measured directly but must be found by calculation, substituting 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*: 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*: make an algebraic deduction to prove a given equation. The candidate must state clearly the terms being used.
18. (a) *Sketch, when applied to graph work*: 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*: implies that simple, freehand drawing is allowed. However, the candidate should take care over proportions and should show important details clearly.
19. *Compare*: give **both** the similarities and differences between things or concepts.
20. *Recognise*: identify facts, characteristics or concepts that are relevant and/or appropriate to understanding a situation, event, process or phenomenon.
21. *Classify*: 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.

6. 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/examsofficers**

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.

Back to contents page

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 for your administrative zone can be found in the *Cambridge Guide to Making Entries*.

Learning outcomes removed from the syllabus content

The following learning outcomes have been removed from the 2015 version of the syllabus.

A Level only learning outcomes are indicated in **bold type**.

G	(i)	outline the roles of nitrate ions and of magnesium ions in plants
H	(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	(a)	define the terms *habitat*, *niche*, *population*, *community* and *ecosystem* and be able to recognise examples of each
	(b)	explain the terms *autotroph*, *heterotroph*, *producer*, *consumer* and *trophic level* in the context of food chains and food webs
	(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*)
N	**(b)**	**define the term *excretion* and explain the importance of removing nitrogenous waste products and carbon dioxide from the body**
	(l)	**explain what is meant by the term *endocrine gland***
	(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**
	(o)	**outline the need for, and the nature of, communication systems within flowering plants to respond to changes in the internal and external environment**
Q	**(d)**	**describe the reasons why one named species has become endangered, and use this information in the context of other endangered species**
R	**(b)**	**explain the advantages of treating diabetics with human insulin produced by gene technology**
S	**(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***
	(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)**
T	**(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**
U	**(a)**	**[PA] describe the histology of the mammalian ovary and testis**
	(e)	**discuss and evaluate the biological, social and ethical implications of the use of contraception**

Back to contents page

Cambridge International Examinations
1 Hills Road, Cambridge, CB1 2EU, United Kingdom
Tel: +44 (0)1223 553554 Fax: +44 (0)1223 553558
Email: info@cie.org.uk www.cie.org.uk

9160746266