Syllabus

Cambridge International A & AS Level Biology
Syllabus code 9700
For examination in June and November 2012

UNIVERSITY of CAMBRIDGE
International Examinations

Contents

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Alterations to the syllabus content are indicated by black vertical lines on both sides of the text.

1. Introduction

1.1 Why choose Cambridge?

University of Cambridge International Examinations (CIE) is the world's largest provider of international qualifications. Around 1.5 million students from 150 countries enter Cambridge examinations every year. What makes educators around the world choose Cambridge?

Recognition

A Cambridge International A or AS Level is recognised around the world by schools, universities and employers. The qualifications are accepted as proof of academic ability for entry to universities worldwide, though some courses do require specific subjects. Cambridge International A Levels typically take two years to complete and offer a flexible course of study that gives students the freedom to select subjects that are right for them. Cambridge International AS Levels often represent the first half of an A Level course but may also be taken as a freestanding qualification. They are accepted in all UK universities and carry half the weighting of an A Level. University course credit and advanced standing is often available for Cambridge International A/AS Levels in countries such as the USA and Canada. Learn more at **www.cie.org.uk/recognition**.

Support

CIE provides a world-class support service for teachers and exams officers. We offer a wide range of teacher materials to Centres, plus teacher training (online and face-to-face) and student support materials. Exams officers can trust in reliable, efficient administration of exams entry and excellent, personal support from CIE Customer Services. Learn more at **www.cie.org.uk/teachers**.

Excellence in education

Cambridge qualifications develop successful students. They not only build understanding and knowledge required for progression, but also learning and thinking skills that help students become independent learners and equip them for life.

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

CIE is part of Cambridge Assessment, a not-for-profit organisation and part of the University of Cambridge. The needs of teachers and learners are at the core of what we do. CIE invests constantly in improving its qualifications and services. We draw upon education research in developing our qualifications.

1. Introduction

1.2 Why choose Cambridge International A & AS Level Biology?

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

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

1.3 Cambridge Advanced International Certificate of Education (AICE)

Cambridge AICE is the group award of Cambridge International Advanced Supplementary Level and Advanced Level (AS Level and A Level).

Cambridge AICE involves the selection of subjects from three curriculum areas – Mathematics and Science; Languages; Arts and Humanities.

1. Introduction

An A Level counts as a double-credit qualification and an AS Level as a single-credit qualification within the Cambridge AICE award framework. Half-credits are also available in English Language and Literature in English and may be combined to obtain the equivalent of a single credit.

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

The examinations are administered in May/June and October/November sessions each year. A candidate working towards the Cambridge AICE Diploma may use up to three sessions to take the equivalent of six credits as long as they are taken within a 13-month period.

Biology (9700) falls into Group A, Mathematics and Sciences.

Learn more about AICE at **http://www.cie.org.uk/qualifications/academic/uppersec/aice**.

1.4 How can I find out more?

If you are already a Cambridge Centre

You can make entries for this qualification through your usual channels, e.g. CIE Direct. If you have any queries, please contact us at **international@cie.org.uk**.

If you are not a Cambridge Centre

You can find out how your organisation can become a Cambridge Centre. Email us at **international@cie.org.uk**. Learn more about the benefits of becoming a Cambridge Centre at **www.cie.org.uk**.

2. Assessment at a glance

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- Candidates for Advanced Subsidiary (AS) certification take Papers 1, 2 and either 31 or 32 in a single exam session.
- Candidates who already have AS certification and wish to achieve the full Advanced Level qualification may carry their AS marks forward and take just Papers 4 and 5 in the exam session in which they require certification.
- Candidates taking the complete Advanced Level qualification take all five papers in a single exam session.

Candidates may not enter for single papers either on the first occasion or for re-sit purposes. Candidates may only enter for the papers in the combinations indicated above.

Paper	Type of Paper	Duration	Marks	Weighting	
				AS Level	A Level
1	Multiple Choice	1 hour	40	31%	15%
2	AS Structured Questions	1 hour 15 min	60	46%	23%
31/32	Advanced Practical Skills	2 hours	40	23%	12%
4	A2 Structured Questions	2 hours	100		38%
5	Planning, Analysis and Evaluation	1 hour 15 min	30		12%

Paper 1

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

Paper 2

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

2. Assessment at a glance

Paper 31/Paper 32

In some examination sessions, two versions of the Advanced Practical Skills paper will be available, identified as Paper 31 and Paper 32. In other sessions only Paper 31 will be available.

Paper 31 and Paper 32 will be equivalent and each candidate will be required to take only one of them. This is to allow large Centres to split candidates into two groups: one group will take Paper 31, the other group will take Paper 32. Each of these papers will be timetabled on a different day.

Each of these practical papers will consist of two approximately equal parts, one of which will require the use of a microscope with low-power and high-power objectives and an eye-piece graticule (see Section 6.2.2 for details). Centres are expected to use eyepiece graticules and stage micrometer scales during teaching. **For the examination, Centres should provide eyepiece graticules as standard. However, CIE will supply stage micrometer scales for the examination as needed.**

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

Candidates will answer all the questions on the question paper. Although no dissection of materials of animal origin will be set in Paper 31/32, dissection, interactive videos or similar will continue to be a useful aid to teaching e.g. when the heart is being studied.

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

Paper 4

This paper will consist of two sections.

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

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

Candidates will answer all questions on the question paper.

Paper 5

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

2. Assessment at a glance

Availability

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

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.

Centres in the UK that receive government funding are advised to consult the CIE 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 session with any other CIE syllabus, except syllabuses with the same title at the same level.

3. Syllabus aims and objectives

CIE has designed this syllabus to give flexibility to both teachers and candidates and to place greater emphasis on understanding and applying scientific concepts and principles than on recalling factual material, while still giving a thorough introduction to the study of biology.

Centres and candidates may choose:

- to take all Advanced Level components in the same exam session, leading to the full A Level
- to follow a **staged** assessment route to the Advanced Level by taking the Advanced Subsidiary (AS) qualification in an earlier exam session. Given satisfactory performance, these candidates are only required to complete the final part of the assessment (referred to in this syllabus as A2) to be granted the full A Level
- to take the Advanced Subsidiary (AS) qualification only.

3.1 Aims

A course based on this syllabus should aim to:

1 Provide, through well-designed studies of experimental and practical biological science, a worthwhile educational experience for all students, whether or not they go on to study science beyond this level. In particular, it should enable them to:
   - become confident citizens in a technological world, with an informed interest in scientific matters;
   - recognise the usefulness (and limitations) of scientific method, and its application in other subjects and in everyday life;
   - be suitably prepared for studies in biological sciences beyond A Level, in further or higher education, and for professional courses.

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

3 Develop attitudes relevant to biological science, such as:
   - concern for accuracy and precision
   - objectivity
   - integrity
   - skills of enquiry

3. Syllabus aims and objectives

- initiative
- inventiveness.

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

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

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

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

3. Syllabus aims and objectives

3.2 Assessment objectives

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

A: Knowledge with understanding

B: Handling information and solving problems

C: Experimental skills and investigations.

A: Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of:

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

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

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

4 scientific quantities and their determination;

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

Questions testing these objectives will often begin with one of the following words: *define*, *state*, *name*, *describe*, *explain (using your knowledge and understanding)* or *outline* (see the glossary of terms in Section 14).

B: Handling information and solving problems

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

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

2 translate information from one form to another;

3 manipulate numerical and other data;

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

5 give reasoned explanations for phenomena, patterns and relationships;

6 make predictions and hypotheses;

7 apply knowledge, including principles, to new situations;

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

9 solve problems.

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

Questions testing these objectives will often begin with one of the following words: *discuss*, *predict*, *suggest*, *calculate*, *explain (give reasoned explanations and explain the processes of using information and solving problems)* or *determine* (see the glossary of terms in Section 14).

C: Experimental skills and investigations

Candidates should be able to:

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

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

3.3 Weighting of assessment objectives

The weighting given to the assessment objectives is:

Assessment objective	Weighting (%)	Assessment components
A: Knowledge with understanding	45	Papers 1, 2 and 4
B: Handling information and solving problems	32	Papers 1, 2 and 4
C: Experimental skills and investigations	23	Papers 31/32 and 5

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

3.4 Additional information

Nomenclature

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

Decimal markers

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

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

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

4. Syllabus content

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

4.1 Structure of the syllabus

1 Core syllabus

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

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

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

2 Applications of Biology

AS Level candidates will not be assessed on these sections.

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

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

4. Syllabus content

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

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

Teachers should include the social, environmental, economic and technological aspects of biology wherever possible throughout the syllabus (see **Aims** 4 and 5 on Page 9). Some examples are included in the syllabus, and teachers should encourage students to apply the principles of these examples to other situations introduced in the course. The number of examples in the syllabus has been limited so that students are not overloaded by factual recall.

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

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

Everything that we know about biology has been learned through practical investigation. Students also find practical work motivating and interesting, and it can help them to understand abstract theoretical concepts. CIE expects that practical activities will underpin the teaching of the whole syllabus.
[PA] next to the learning outcomes in the syllabus content show parts of the subject that are particularly suitable for practical work.

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

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

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

4.2 Core syllabus

A Cell structure

Content

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

Learning Outcomes

Candidates should be able to:

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

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

(c) describe and interpret drawings and photographs of typical animal and plant cells, as seen under the electron microscope, recognising the following: rough and smooth endoplasmic reticula, Golgi apparatus, mitochondria, ribosomes, lysosomes, chloroplasts, cell surface membrane, nuclear envelope, centrioles, nucleus and nucleolus;

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

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

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

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

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

(i) describe the structure of a prokaryotic cell and compare and contrast the structure of prokaryotic cells with eukaryotic cells;

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

B Biological molecules

Content

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

Learning Outcomes

Candidates should be able to:

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

(b) describe the ring forms of α-glucose and β-glucose;

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

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

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

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

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

(h) describe the molecular structure of haemoglobin as an example of a globular protein, and of collagen as an example of a fibrous protein and relate these structures to their functions (the importance of iron in the haemoglobin molecule should be emphasised);

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

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

C Enzymes

Content

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

Learning Outcomes

Candidates should be able to:

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

(b) explain the mode of action of enzymes in terms of an active site, enzyme/substrate complex, lowering of activation energy and enzyme specificity;

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

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

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

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

D Cell membranes and transport

Content

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

Learning Outcomes

Candidates should be able to:

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

(b) outline the roles of cell surface membranes;

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

(d) **[PA]** investigate the effects on plant cells of immersion in solutions of different water potential;

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

E Cell and nuclear division

Content

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

Learning Outcomes

Candidates should be able to:

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

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

(c) explain how uncontrolled cell division can result in cancer and identify factors that can increase the chances of cancerous growth;

(d) explain the meanings of the terms *haploid* and *diploid* and the need for a reduction division (meiosis) prior to fertilisation in sexual reproduction;

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

F Genetic control

Content

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

Learning Outcomes

Candidates should be able to:

(a) describe the structure of RNA and DNA and explain the importance of base pairing and the different hydrogen bonding between bases;

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

(c) state that a gene is a sequence of nucleotides as part of a DNA molecule, which codes for a polypeptide and state that a mutation is a change in the sequence that may result in an altered polypeptide;

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

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

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

G Transport

Content

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

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

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

(h) describe the pathways and explain the mechanisms by which water is transported from soil to xylem and from roots to leaves;

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

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

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

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

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

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

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

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

(q) describe the role of haemoglobin in carrying oxygen and carbon dioxide;

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

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

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

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

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

(w) describe the cardiac cycle;

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

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

H Gas exchange and smoking

Content

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

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

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

(h) explain the link between smoking and atherosclerosis, coronary heart disease and strokes;

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

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

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

I Infectious disease

Content

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

Learning Outcomes

Candidates should be able to:

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

(b) describe the causes of the following diseases: cholera, malaria, TB, HIV/AIDS, smallpox and measles;

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

(d) discuss the roles of social, economic and biological factors 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 global patterns of distribution of malaria, TB and HIV/AIDS and assess the importance of these diseases worldwide;

(f) outline the role of antibiotics in the treatment of infectious diseases;

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

J Immunity

Content

- The immune system
- Vaccination

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

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

(h) discuss the reasons why vaccination has eradicated smallpox but not measles, TB, malaria, sickle cell anaemia or cholera;

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

K Ecology

Content

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

Learning Outcomes

Candidates should be able to:

(a) define the terms *habitat*, *niche*, *population*, *community* and *ecosystem* and state examples of each;

(b) explain the terms *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 microorganisms;

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

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

L Energy and respiration

Content

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

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

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

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

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

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

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

(l) **define the term *respiratory quotient* (RQ);**

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

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

M Photosynthesis

Content

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

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

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

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

N Regulation and control

Content

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

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

O Inherited change

Content

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

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

(f) **[PA] use the chi-squared test to test the significance of differences between observed and expected results (the formula for the chi-squared test will be provided);**

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

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

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

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

P Selection and evolution

Content

- **Natural and artificial selection**

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

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

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

4.3 Applications of Biology

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

Q Biodiversity and conservation

Content

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

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

R Gene technology

Content

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

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

(g) **[PA] outline the principles of electrophoresis as used in:**
  - **genetic fingerprinting**
  - **DNA sequencing;**

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

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

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

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

S Biotechnology

Content

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

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

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

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

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

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

T Crop plants

Content

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

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

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

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

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

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

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

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

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

U Aspects of human reproduction

Content

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

Learning Outcomes

Candidates should be able to:

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

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

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

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

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

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

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

5. Definitions

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

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

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

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

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

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

5. Definitions

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

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

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

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

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

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

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

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

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

5. Definitions

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

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

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

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

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

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

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

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

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

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

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

5. Definitions

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

The genetic dictionaries that will be used are given below:

mRNA genetic dictionary

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

5. Definitions

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

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

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

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

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

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

5. Definitions

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

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

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

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

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

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

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

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

5. Definitions

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

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

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

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

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

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

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

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

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

5. Definitions

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

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

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

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

It can also be determined theoretically by calculation: $$RQ = \frac{CO_2 produced}{O_2 used}$$

e.g., for a carbohydrate: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ $$RQ = \frac{6}{6} = 1$$

e.g., for a lipid: $2C_{57}H_{110}O_6 + 163O_2 \rightarrow 114CO_2 + 110H_2O$ $$RQ = \frac{114}{163} = 0.7$$

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

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

Tidal volume: the volume of air breathed in or out during a single breath during normal ventilation at rest or during exercise.

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

5. Definitions

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

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

Vital capacity: the volume of air that can be forced out of the lungs after a maximal inspiration.

6. Practical assessment

6.1 Introduction

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

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

Candidates' experimental skills are assessed in Papers 31/32 and 5. In each of these papers, the examiners are not strictly bound by the subject content of the syllabus when finding contexts for setting questions. Within unfamiliar contexts, candidates are told exactly what to do and how to do it. Within familiar contexts listed in the syllabus, the candidates are expected to know how to use the techniques. Knowledge of theory and experimental skills will only be drawn from within the syllabus. Examples of unfamiliar contexts might include:

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

6. Practical assessment

6.2 Paper 31/32

In some examination sessions, two versions of the Advanced Practical Skills paper will be available, identified as Paper 31 and Paper 32. Paper 31 and Paper 32 will contain different questions, but will be equivalent in the skills assessed and in the level of demand. Each candidate should take one of these papers.

Where two versions of the paper are offered, some schools may wish to divide their candidates so that some are entered for Paper 31 and the others are entered for Paper 32; other schools may wish to enter all of their candidates for the same paper.

Paper 31/32 is a timetabled, laboratory-based practical paper that focuses on the following experimental skills:

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

Each paper:

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

Paper 31 and Paper 32 will contain different questions, but are equivalent in the skills that they assess and in the level expected from the candidate. Each candidate must take one of these papers. Centres can decide whether to divide their candidates so that some take Paper 31 and the others take Paper 32 or to enter enter all of their candidates for the same paper.

6. Practical assessment

6.2.1 Mark scheme for Paper 31/32

Paper 31/32 is marked using the mark scheme shown in the table. The sections following the table list the expectations for each mark category.

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

6.2.2 Manipulation, measurement and observation

Successfully collecting data and observations

Candidates should be able to:

- set up apparatus correctly;
- follow instructions given in the form of written instructions or diagrams;
- use their apparatus to collect an appropriate quantity of data or observations, including subtle differences in colour or other properties of materials;
- make measurements using millimetre scales, graticules, protractors, stopwatches, balances, measuring cylinders, syringes, thermometers, and other common laboratory apparatus.

Candidates will be expected to use light microscopes. They should be able to place the slide on the stage, arrange the lighting appropriately and focus on the specimen at both low-power (objective lens x10, sometimes described as 16 mm or 2/3") and high-power (objective lens x40, or 4 mm or 1/6"), using a microscope with a graticule in the eyepiece. The eyepiece lens should be x10.

6. Practical assessment

Making decisions about measurements or observations

Candidates should be able to:

- decide how many tests, measurements or observations to carry out;
- make measurements or observations that span the largest possible range within the limits either of the equipment provided or of the instructions given;
- make quantitative measurements or qualitative observations that are appropriately distributed within this range;
- decide how long to leave experiments running before making readings;
- repeat readings or observations as necessary;
- make and record enough accurate measurements and observations.

Candidates may need to choose how many tests, measurements and observations can be made in the time available. In some experiments, this should be a regularly spaced set of measurements. For other experiments, such as those where the candidate must find the peak value of a curved graph, the candidate may have to concentrate the measurements in one part of the range being investigated. Candidates are expected to be able to decide the most appropriate distribution of values. In qualitative experiments, candidates must use precise descriptions and comparisons of colour or other observations.

In experiments such as those involving enzymes, any of three different methods of taking measurements may be appropriate:

- candidates may need to measure the initial rate of reaction (in which case they should take measurements as quickly as possible);
- the rate of reaction may be constant over several minutes, or colour changes may take several minutes to occur (in which case candidates should leave the experiment to run for as long as possible);
- an end point must be reached (in which case candidates should run the experiment until the end point is reached or the time runs out).

Repeated readings of particular quantities are often necessary in biology, because experimental errors and variation in the activity of biological materials are large and an average value is more representative. Candidates should repeat any individual readings or observations that do not seem to fit the pattern of measurement. A candidate may have to decide how many times to let something repeat before recording the observation (for example, in counting the number of bubbles released from a delivery tube).

Candidates may be given marks for:

- measured quantitative data in which the values found are reasonable;
- qualitative observations that are consistent with the materials supplied.

It is important that candidates make enough distinct observations, for example to:

- show all the structures that can be seen in a defined part of a specimen,
- identify the dissolved substances in a solution.

When assessing the accuracy of a candidate's data, the examiners will only consider the extent to which the candidate has affected the quality of the data. They will take into account any limits in the quality of data caused by the experimental method given or by the apparatus and materials used. When making such accuracy assessments, the examiners may study the scatter of points on a graph, or they may compare the candidate's data or observations with information supplied by the supervisor or known to the examiners.

6.2.3 Presentation of data and observations

Recording data or observations

Candidates should be able to:

- present numerical data, values or observations in a single table of results;
- make the table before taking readings/making observations, so that they can write results straight into the table;
- if necessary, include, columns for raw data, for calculated values and for deductions in the table of results;
- use column headings that include the quantity and the unit (as appropriate) and that fit with accepted scientific conventions;
- record raw readings of a quantity to the same degree of precision and record observations to the same level of detail.

An example of accepted practice in column headings: if the quantity being measured is length in millimetres, then the candidate should write the column heading as 'length / mm', but 'length in mm' or 'length (mm)' would be allowed. Candidates must not write 'length mm' or just 'mm'. Candidates may write the quantity or the unit or both in words or appropriate symbols, provided that their meaning is clear and unambiguous in the context. Candidates should avoid using 't', because it may be used for both time and temperature. Candidates can use conventional symbols or abbreviations (such as 'ATP' for adenosine triphosphate or 'r' for radius) without explaining them.

6. Practical assessment

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

Candidates should record observations of qualitative variables such as colour in simple language such as 'blue' or 'orange'. Where fine discrimination is needed, candidates should use extra terms such as 'pale' or 'dark', and they should use comparisons such as 'darker red than at 3 minutes' or 'paler green than at 0.2 mol dm^{-3}, but darker than at 0.4 mol dm^{-3}'. It is important for candidates to avoid ambiguous descriptions of colour (such as 'pinkish purple' or 'yellowy-green'). Candidates should be able to describe positive and negative results of the biochemical tests in the syllabus precisely, using terms such as 'purple' for the positive result of the biuret test.

Displaying calculations and reasoning

Candidates should be able to:

- show their working in calculations, and the key steps in their reasoning;
- use the correct number of significant figures for calculated quantities.

Where candidates make calculations, they should show all the key stages in the calculation, so that the examiners can give credit for the candidate correctly displaying working even if the final answer is incorrect. Similarly, where observations are the basis for logical deduction (for example, the concentration of an unknown solution or the identity of an unknown solute), candidates should show the main steps in making the deduction. Where a candidate uses inductive thought processes to build up a general prediction or to support a general theory from specific observations, they should give the sequence of major steps used.

Candidates should give calculated quantities to the same number of significant figures as the measured quantity that has the smallest number of significant figures. For example, if a candidate collects values of time measured to 1 significant figure and values of gas volume measured 2 significant figures, then the calculated rate should be given to 1 significant figure, but not 2 or more. Centres can find more information about significant figures at **www.chemsoc.org/networks/learnnet/RSCmeasurements.htm**.

Data layout

Candidates should be able to:

- choose a suitable and clear method of presenting the data, such as table, chart, graph, drawing or a mixture of methods;
- decide which variable(s) to plot and plot them appropriately, on clearly labelled x- and y-axes;
- plot all points or bars to an appropriate accuracy;
- follow the IOB recommendations for putting lines on graphs.

Generally, candidates should present data in the form that allows the key points to be visualised most clearly:

- for quantitative data, this is likely to be a graph;
- for qualitative data this may be a table;
- for anatomical or histological data it is likely to be a drawing.

Candidates should:

- choose scales for the graph axes that make it easy to read the graph, such as 1, 2 or 5 units to a 20 mm square;
- make the best use of the space available, using over half of the length and width of the grid;
- make tables of data and observations large enough so that all the entries can be comfortably fitted in the available space;
- make drawings large and without shading, so that errors are small, and use fine, clear, unbroken lines, showing the outlines of structures clearly;
- use pencil for drawings, lines on tables and graphs.

The accepted scientific conventions for labelling the axes of a graph are the same as for the column headings in a table of results, with both the quantity and the unit shown (where appropriate). Candidates should draw points finely with a sharp pencil, but make sure that the points are still visible. A fine cross or an encircled dot is suitable; a thick pencil blob is not. It is often obvious that the data fall on a straight line or smooth curve, and then a line of best fit or an appropriate curve should be placed on the graph. Sometimes it is not possible to be sure if the line should be straight or a smooth curve, so the candidate should join adjacent points by straight ruled lines. This represents the data with the fewest assumptions possible. Lines of best fit should show an even distribution of points on either side of the line along its whole length. Lines should be finely drawn and should not contain kinks or breaks.

6.2.4 Analysis, conclusions and evaluation

Interpreting data or observations and identifying sources of error
Candidates should be able to:

- describe the patterns and trends shown by tables and graphs;
- describe and summarise the key points of a set of observations;
- find an unknown value by using co-ordinates or axis intercepts on a graph;
- calculate other quantities from data or from quantitative data related to their qualitative observations, or calculate the mean from replicate values, or make other appropriate calculations;
- find the gradient of a straight-line graph or tangent to a curve;
- evaluate how effectively variables have been controlled and so how much confidence can be placed in any conclusions made;
- point out the most significant sources of error in an experiment;
- estimate, quantitatively, the uncertainty in quantitative measurements and make comments on the reliability of data;
- express such uncertainty in a measurement as an actual or percentage error;
- show understanding of the distinction between systematic errors and random errors.

Candidates should give precise descriptions and quote figures to support the description, with calculated values where these are appropriate. Unknown values could include unknown concentrations where a calibration curve has been drawn, or values for 50% plasmolysis or zero change in mass in osmosis experiments. Calculations may involve mean, percentage, percentage gain or loss, rate of reaction, magnification, actual size or other appropriate calculations. When a candidate must find a gradient, they should choose points on the line that are separated by at least half of the length of the line or tangent drawn.

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

For key control variables, candidates should be able to give a realistic estimate or appraisal of how effectively the variable was controlled (for example, how closely the temperature was kept the same across a number of samples) and therefore give an indication of their confidence in any conclusions made.

Drawing conclusions
Candidates should be able to:

- make conclusions from an experiment, giving an outline description of the main features of the data, considering whether experimental data supports a given hypothesis, and making further predictions;
- make conclusions from interpreting observations, data and calculated values;
- give scientific explanations of the data, observations and conclusions that they have described, using the skills, knowledge and understanding that they have got from studying the AS Biology syllabus.

The examiners will give hypotheses that are being tested in AS practical papers, although hypothesis formulation is in skill B and so can be tested in the theory components. Candidates can express conclusions in terms of whether they support or disprove hypotheses, or in terms of the straightforward deductions or inductions that can logically be made from the data, observations or results of calculations. Simple scientific explanations form a part of such conclusions and therefore form a part of this practical assessment. The candidates should refer to knowledge and understanding gained in the theory part of the course when they provide explanations of their practical conclusions.

Suggesting improvements
Candidates should be able to:

- suggest modifications to an experimental arrangement that will improve the accuracy of the experiment or the accuracy of the observations that can be made, including using new methods or strategies to investigate the question and describe such modifications clearly in words or diagrams;
- suggest ways of extending the investigation to answer a new question.

Candidates' suggestions should be realistic (that is, it must be possible to carry them out in practice, although they may include the use of apparatus that is not available to the candidate, such as a colorimeter). The suggestions can be linked to either the apparatus used, the experimental procedure followed or the nature of the observations or the means used to make them. Candidates can include improvements that they have actually made while carrying out the experiment, such as repeating readings. The suggested modifications may be linked to sources of error identified by the candidate or to other sources of error. When asked for modifications, candidates should not give extensions to answer new questions.

6.2.5 Apparatus required for Paper 31/32

The apparatus required for Paper 31/32 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. If Centres have any doubt at all how the practical examinations should be set up, they must contact CIE as soon as possible.

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

6. Practical assessment

6.3 Paper 5

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

- planning;
- analysis and evaluation.

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

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

Centres must allow for many hours of laboratory-based work, and must make sure that teachers give careful supervision to make sure that candidates carry out experiments with due regard to safety.

The paper has two or more questions with a total of 30 marks available. Candidates must design an experimental investigation for a given problem. The questions are not highly structured: candidates must answer using extended, structured writing, and use appropriate diagrams and tables as illustrations. Candidates may have to express a prediction as a written hypothesis linking independent and dependent variables, or as a graph showing the expected result. Some activities require the candidate to make analyses, evaluations and conclusions. For these questions, the candidates are given some experimental data. Again, these questions are not highly structured, and candidates must decide for themselves how to analyse and evaluate the data, and what conclusions to make.

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

6.3.1 Mark scheme for Paper 5

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

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

6.3.2 Planning

Defining the problem

Candidates should be able to:

- identify the dependent and independent variable in the experiment or investigation;
- express the aim of the experiment or investigation as a prediction or hypothesis, both in words and in the form of a predicted graph;
- identify which variables must be controlled.

Candidates are provided with a scenario and background information to give the context within which they must define the problem. They should be able to use this information to work out the key variables in the investigation. Candidates should be able to make a hypothesis. This should be a quantitative, testable, falsifiable prediction of the likely outcome, based on the information given in the question and on their knowledge and understanding of the topic being considered. Candidates may have to express their hypothesis in the form of a sketch graph showing the expected result. They must give a list of key variables to control in order to test the hypothesis effectively. They should only include variables that are likely to have some effect on the material involved (e.g. temperature), but not those likely to have a very small effect (e.g. using the same test-tube).

Methods

Candidates should be able to:

- describe the method they would use to vary the independent variable, and the ways in which they would make sure that they had measured its values accurately;
- describe how they would measure the dependent variable;
- describe how they would control each of the other key variables;
- explain how they would use any control experiments to make sure that it is the independent variable that is affecting the dependent variable and not some other factor;
- describe the arrangement of apparatus and the steps that they would use in the procedure;
- suggest appropriate volumes and concentrations of reagents, and explain how different concentrations would be prepared;
- assess the risks of their proposed methods;
- describe precautions that they would take to keep risks as low as possible;
- make tables for data that they might wish to record;
- describe how the data might be used to reach a conclusion.

The overall arrangement should be possible to set up. The candidate should produce a plan where they could collect the necessary data without too much difficulty if the apparatus were assembled as described. Candidates should use words and labelled diagrams for describing the apparatus and how to use it. The measuring instruments chosen should measure the correct quantity to a suitable precision. Control experiments can be of the type where all factors are identical to the experimental treatment (except that the value of the independent variable is zero), or they may be of the type used to confirm that, for example, it is an enzyme that is causing a particular effect, by leaving out or denaturing the enzyme.

Candidates should be able to explain how to make up solutions:

- in % (w/v), for example by adding a known mass of solute to a small volume of solvent, mixing until fully dissolved and then making up to the final volume with solvent;
- in mol dm^{-3}, by dissolving the molar mass of solute and then making up to 1 dm^3 with solvent;
- by using serial dilution.

Candidates should be able to carry out a simple risk assessment of their plan, identifying the areas where accident or injury is most likely to happen and the areas where it would be most serious. They should be able to use this to suggest appropriate safety precautions specifically related to the risks that they have identified. For example, they might point out that protease enzyme solutions pose a particular risk to the cornea if they are splashed, and that wearing eye protection would therefore be an appropriate precaution.

Candidates should be able to describe the main steps that they would use in order to get to the point of being able to make conclusions, including (as appropriate) preparing results tables, proposing graphs to plot, giving the key points to consider in any evaluation of the method and results, and making reference back to the hypothesis.

6.3.3 Analysis, conclusions and evaluation

Dealing with data
Candidates should be able to:

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

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

Candidates should know how to choose and construct appropriate data tables, including columns for calculated values, and headings including quantity and unit (where appropriate). They should also be able to draw suitable graphs displaying the independent variable on the x-axis and the dependent variable on the y-axis, and satisfying the criteria laid out in the Paper 31/32 (Section 7). In addition, they should include confidence limit error bars, calculated using standard error.

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

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

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

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

Further **Notes on the Use of Statistics in Biology** can be found at Section 7.5.

Evaluation
Candidates should be able to:

- spot anomalous values in provided data and suggest how to deal with such anomalies;
- within familiar contexts, suggest possible explanations for anomalous readings;
- assess whether the provided readings have been replicated sufficiently, and describe the adequacy of the range of data given;
- use the information given to assess whether selected variables have been controlled effectively;
- use these evaluations and the information given to make informed judgements about how much confidence can be put in any conclusions.

In a table or graph of data, candidates should be able to spot values that are clearly anomalous, and suggest strategies for dealing with such anomalies, including repeating the experiment or leaving out the affected data. Where investigations use familiar contexts, which the candidates have explored during the course (those marked **[PA]** in the syllabus content), candidates can be asked to suggest possible causes for such anomalies (above and beyond 'investigator error'), and are rewarded for answers taken from their own experience of problems built in to the particular investigation.

Candidates must know why replicating data is important and the practical limits on replication. Candidates must be able to show instances where the investigator should have taken readings at lower or higher values of the independent variable in order to give a complete range of values. They must also be able to point out situations where there are gaps in the range that reduce the information that the investigation can give (for example, around a key turning point).

Candidates may be given information that will help them to assess the extent to which a particular variable has been effectively controlled (such as the temperature recorded within each of a number of samples in which it is supposed to be the same).

Candidates should be able to bring all this information together and so to make informed judgements about how reliable the investigation is and how much it can be trusted for testing the hypothesis.

Conclusions
Candidates should be able to:

- draw conclusions from an investigation, giving a detailed description of the key features of the data and analyses, and considering whether experimental data supports a given hypothesis;
- give detailed scientific explanations of the data and of their conclusions, using the skill, knowledge and understand that they have gained from their studies of the AS and A2 syllabus;
- make further predictions, ask informed and relevant questions and suggest improvements;

6. Practical assessment

The candidates should give key points of the raw data, graphical representations of it and statistical test results, including quoting relevant figures. They should clearly show the strength or weakness of any support for or against the hypothesis. In particular, they should be able to show whether the hypothesis has been proved or disproved. The conclusions should include detailed scientific explanations and these should play an important part in this higher-order practical skill assessment. The candidates must refer to knowledge and understanding gained in the theory part of the course to give explanations of their practical conclusions. For example, candidates should make detailed reference to the rate of effective collisions between enzyme molecules and substrates to explain the conclusions made about an enzyme-related hypothesis.

Where appropriate, candidates should have the chance to ask questions based on their conclusions and so to derive further predictions and hypotheses. Within familiar contexts and in relation to the evaluations they have made, candidates may have the chance to suggest how the investigation could be improved to increase the confidence in drawing conclusions.

7. Appendix

7.1 Safety in the laboratory

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

Associations

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

Websites

www.chemsoc.org/networks/learnnet/Safety.htm
www.ncbe.reading.ac.uk/NCBE/SAFETY/menu.html
www.microbiologyonline.org.uk/safety.html

Publications

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

UK Regulations

Control of Substances Hazardous to Health Regulations (COSHH) 2002, available at **www.opsi.gov.uk/SI/si2002/20022677.htm**.
A brief guide can be found at **www.hse.gov.uk/pubns/indg136.pdf**.

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

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

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7.2 Laboratory equipment

This is a list of basic materials and apparatus that a well-equipped biology laboratory would contain. The list is *not* comprehensive.

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
- Specimen tubes with corks
- A means of heating – Bunsen burners or similar
- Thermometers
- Measuring cylinders
- Means of measuring small volumes, such as syringes (various sizes)
- Teat pipettes
- Beakers
- Tripod stands and gauzes
- Filter funnels and filter paper
- Petri dishes (plastic) or similar small containers
- White tiles or other suitable surfaces on which to cut
- Glass slides and coverslips
- Conical flasks
- Clamp (retort) stands and bosses
- Visking (dialysis) tubing
- Capillary tubing
- Soda glass tubing
- Paper towelling or tissue

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- Cotton wool
- Solid glass rods
- 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
- 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
- Bench lamp with flexible arm
- Balance (to 0.1 g)
- Water-baths or equivalent
- Cork borers
- Stopclock/timer showing seconds
- Simple respirometer – can be 'homemade'
- Pipe cleaners/other suitable aid to demonstrate mitosis and meiosis
- Apparatus to measure rate and depth of breathing
- Culture bottles, autoclave
- Inoculating wires/bioloops
- Haemocytometers
- Tape for sealing dishes
- Cultures of live yoghurt
- Appropriate cultures of microorganisms, such as *Escherichia coli, Bacillus subtilis*

Stocks of:

- [**H**] – Iodine in potassium iodide solution
- [**H**] – Benedict's solution
- [**C**] – Biuret reagent/potassium hydroxide and copper sulfate solution
- [**F**] – Ethanol (for fats test)
- [**F**] – Methylated spirit (for extraction of chlorophyll)

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- Sucrose (use AR for non-reducing sugar test)
- Glucose
- Starch
- [**C**] – Potassium hydroxide
- Sodium chloride
- [**H**] – Dilute hydrochloric acid
- Hydrogen carbonate indicator
- Sodium bicarbonate/sodium hydrogen carbonate
- [**H**] – Limewater
- Distilled/deionised water
- Universal Indicator paper and chart
- Litmus paper
- Eosin/red ink
- [**H**] – Methylene blue
- Vaseline/petroleum jelly (or similar)
- DCPIP (dichlorophenol-indophenol)
- Ascorbic acid (vitamin C)
- [**H**] – Enzymes: amylase, trypsin (or bacterial protease)
- Materials for preparing immobilised enzymes: calcium chloride, sodium alginate
- Potatoes (store in fridge) or mung beans (to germinate for use) as a source of catalase
- Non-competitive enzyme inhibitor (e.g. [**H**] – copper sulfate)
- Stains for preparing slides to show mitosis – e.g. carmine acetic
- [**H**] – Feulgen stain (Schiff's reagent)
- Apparatus/chemicals for water cultures to show effect of Mg and N on growth
- Nutrient broth, nutrient agar
- Appropriate disinfectants

Apparatus for sampling animals:

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

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Slides of:

- Mitosis and meiosis
- Anther and ovule
- Pollen, stamen and stigma of wind-pollinated and insect-pollinated plant, vs maize fruit
- ts stem, ts root and ts leaf of a dicotyledonous xerophyte (such as *Erica* or *Ammophila* or local equivalent)
- ts stem, ts root and ts leaf of a dicotyledonous mesophyte (such as *Ligustrum* or *Prunus* or local equivalent)
- Trachea and lungs
- Pancreas
- Arteries/veins/capillaries
- Blood smear
- Kidney
- ts spinal cord
- Ovary and testis
- ts maize leaf, ts rice leaf, ts rice stem, ts rice root, ts sorghum leaf, ts wheat leaf
- Animal and plant cells
- Examples of organisms representing the other three Kingdoms; Protoctista (e.g. *Amoeba*, *Euglena* or locally available equivalents); Prokaryotae (e.g. bacterial smear, cyanobacteria); Fungi (e.g. yeast, *Penicillium*)

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7.3 Resource list

Teachers may find reference to the following books helpful. These titles are just some of the books that were available when this syllabus was printed. Teachers are encouraged to choose books that they feel will interest their students and will support their own teaching style. Titles marked with an asterisk (*) indicate the most suitable books when you have limited choice or availability, and the most suitable books for use as a main text by students.

CIE has endorsed the following book for use with this syllabus

Jones, M, Fosbery, R, Gregory, J, Taylor, D (2007), *CIE Biology AS and A Level*
(CUP, **www.cambridge.org**) ISBN 9780521703062
This is a new edition, which covers the whole syllabus and includes material for the applications syllabus and on statistics.

Other textbooks that teachers will find helpful

Alma, P J (1993) *Environmental Concerns*
(CUP, **www.cambridge.org**) ISBN 9780521428696

Biozone (2004) *Advanced Biology AS*, *Advanced Biology A2* – Student Resource and Activity Manuals
ISBN 9781877329968, 1877329223 – Model Answers ISBN 9781877329975
(Biozone International Ltd., **www.biozone.co.uk**)

Bradfield, P, Dodds, J, Dodds, J and Taylor, N *(2001, 2002) AS level Biology*, *A2 level Biology*
(Pearson Education Ltd., **www.longman.co.uk**) ISBN 9780582429468, 9780582429451

Boyle, M and Senior, K (2002) *Biology*, Collins Advanced Science
(Collins Educational, **www.collinseducation.com**) ISBN 9780007136005

Cadogan, A and Best, G (1992) *Environment and Ecology*, Biology Advanced Studies
(Nelson Thornes, **www.nelsonthornes.com**) ISBN 9780174482154

Carr, M and Cordell, R (1993) *Biochemistry*, Biology Advanced Studies
(Nelson Thornes, **www.nelsonthornes.com**) ISBN 9780174481966

*Chapman, J L and Reiss, M J (1998) *Ecology* (2nd edition)
(CUP, **www.cambridge.org**) ISBN 9780521005753

Clamp, A (2001) *Synoptic Skills in Advanced Biology*
(Hodder Murray, **www.hoddereducation.co.uk**) ISBN 9780340803226

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Clegg, C J and Mackean, D G (2000) *Advanced Biology: Principles and Applications* (2nd edition) (John Murray, **www.johnmurray.co.uk**) ISBN 9780719576706

Clegg, C J, Mackean, D G, Reynolds, R and Openshaw, P (1996) *Advanced Biology Study Guide* (John Murray, **www.johnmurray.co.uk**) ISBN 9780719553585

*Jones, M, Fosbery, R and Taylor, D (2000) *Biology 1*, Cambridge Advanced Sciences (CUP, **www.cambridge.org**) ISBN 9780521787192

*Jones, M and Gregory, J (2001) *Biology 2*, Cambridge Advanced Sciences (CUP, **www.cambridge.org**) ISBN 9780521797146

*Jones, M and Jones, G (1997) *Advanced Biology* (CUP, **www.cambridge.org**) ISBN 9780521484732

Kent, M (2000) *Advanced Biology* (Oxford University Press, **www.oup.co.uk**) ISBN 9780199141951

King, T J, Reiss, M and Roberts, M (2001) *Practical Advanced Biology* (Nelson Thornes, **www.nelsonthornes.com**) ISBN 9780174483083

Marieb, E (2001) *Human Anatomy and Physiology* (5th edition) (Benjamin Cummings, **www.aw.com**) ISBN 9780805349894

Phillips, W D and Chilton, T J (1994) *A-Level Biology* (revised edition) (Oxford University Press, **www.oup.co.uk**) ISBN 9780199145843

*Roberts, M, Monger, G and Reiss, M (2000) *Advanced Biology* (Nelson Thornes, **www.nelsonthornes.com**) ISBN 9780174387329

Rowland, M (1992) *Biology*, Bath Advanced Science (Nelson Thornes, **www.nelsonthornes.com**) ISBN 9780174384250

Siddiqui, S A (1999), *Comprehensive Practical Biology for A Levels* (Ferozsons, Lahore) ISBN 9789690015723

*Taylor, D J, Green, N P O, Stout, G W and Soper, R (1997) *Biological Science 1 and 2* (3rd edition) (CUP, **www.cambridge.org**) ISBN 9780521561785

*Taylor, D (1989) *Human Physical Health*, Cambridge Social Biology Topics (CUP, **www.cambridge.org**) ISBN 9780521313063

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APPLICATIONS SYLLABUS

A Level Science Applications Support Booklet – SA97000105, *Biology* (2006) is available from CIE Publications, 1 Hills Road, Cambridge, CB1 2EU, UK, phone +44 (0) 1223 553553, fax +44 (0) 1223 553558, email **international@cie.org.uk**

Margulis, L, Schwartz, K and Dolan, M (1999) *Diversity of Life: The Illustrated Guide to the Five Kingdoms* (Jones and Bartlett Publishers, **www.jbpub.com**) ISBN 9780763708627

Ratledge, C and Kristiansen, B (2006) *Basic Biotechnology* (3rd edition) (CUP, **www.cambridge.org**) ISBN 9780521549585

Spicer, J (2006) *Biodiversity: A Beginner's Guide* (Oneworld Publications, **www.oneworld-publications.com**) ISBN 9781851684717

Many of the books previously used for the discontinued Options syllabus will be useful for the Applications of Biology syllabus, and are listed below.

Clegg, C J and Mackean, D G (2000) *Advanced Biology: Principles and Applications* (2nd edition) (John Murray, **www.johnmurray.co.uk**) ISBN 9780719576706

Jones, M and Jones, G (1997) *Advanced Biology* (CUP, **www.cambridge.org**) ISBN 9780521484732

Phillips, W D and Chilton, T J (1994) *A-Level Biology* (revised edition) (OUP, **www.oup.co.uk**) ISBN 9780199145843

Taylor, D J, Green, N P O, Stout, G W and Soper, R (1997) *Biological Science 1 and 2* (3rd edition) (CUP, **www.cambridge.org**) ISBN 9780521561785

*Lowrie, P and Wells, S (2000) *Microbiology and Biotechnology* (2nd edition), Cambridge Advanced Sciences (CUP, **www.cambridge.org**) ISBN 9780521787239

Taylor, J (2001) *Microorganisms and Biotechnology* (2nd edition), Bath Advanced Science (Nelson Thornes, **www.nelsonthornes.com**) ISBN 9780174482550

Austin, C R and Short, R V (editors) (1984) *Reproduction in Mammals. Volume 3, Hormonal Control of Reproduction* (CUP, **www.cambridge.org**) ISBN 9780521275941

Avery, R, Cuthill, I, Miller, R and Rowlands, G (1994) *The Five Kingdoms*, Biology Advanced Studies (Nelson Thornes, **www.nelsonthornes.com**) ISBN 9780174482291

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Baggott, L M (1997) *Human Reproduction*, Cambridge Social Biology Topics
(CUP, **www.cambridge.org**) ISBN 9780521469142

*Taylor, D (2001) *Growth, Development and Reproduction* (2nd edition), Cambridge Advanced Sciences
(CUP, **www.cambridge.org**) ISBN 9780521787215

Calladine, C and Drew, H (1997) *Understanding DNA* (2nd edition)
(Academic Press, **www.apcatalog.com**) ISBN 9780121550882

Dyson, T (1994) *The Ethics of In Vitro Fertilization*
(Continuum International Publishing – Mowbray, **www.continuumbooks.com**) ISBN 9780264672830

*Gregory, J (2000) *Applications of Genetics* (2nd edition), Cambridge Advanced Sciences
(CUP, **www.cambridge.org**) ISBN 9780521787253

Hayward, G (1992) *Applied Genetics*, Bath Advanced Science
(Nelson Thornes, **www.nelsonthornes.com**) ISBN 9780174385110

Nicholl, D S T (2002) *An Introduction to Genetic Engineering* (2nd edition), Studies in Biology
(CUP, **www.cambridge.org**) ISBN 9780521004718

Vardy, P (1999) *The Puzzle of Ethics*
(Fount) ISBN 978006281443

BIOLOGY PRACTICAL SKILLS BOOKS

Teaching AS Biology Practical Skills – PSAS97000105 and Teaching A2 Biology Practical Skills – PSA297000105 (2006) are available from CIE Publications, 1 Hills Road, Cambridge, CB1 2EU, UK, phone +44 (0) 1223 553553, fax +44 (0) 1223 553558, email **international@cie.org.uk**

Adds, J, Larkcom, E, Miller, R and Sutton, R (2001) *Tools, Techniques and Assessment in Biology*
(Nelson Thornes Ltd) ISBN 9780174482734

Hayward, D (2003) *Teaching and Assessing Practical Skills in Science*
(CUP, **www.cambridge.org/education/international**) ISBN 9780521753593
This is a resource for teachers to support teaching the syllabus. It was written for IGCSE, but is useful for AS and A Level.

Indge, B (2003) *Data and Data Handling for AS Level*
(Hodder Murray, **www.hoddereducation.co.uk**) ISBN 9780340856475

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King, T, Reiss, M and Roberts, M (2001) *Practical Advanced Biology*
(Nelson Thornes, **www.nelsonthornes.com**) ISBN 9780174483083

Morgan, S (2002) *Practical Work for Biology*
(Hodder & Stoughton, **www.hodderheadline.co.uk**) ISBN 9780340847123

Newton, S (editor) (2006) *International Practical Science Guide*
(ASE and CIE, **www.ase.org.uk**, **www.cie.org.uk**) ISBN 9780863574115

Siddiqui, S A (1999) *Comprehensive Practical Biology for A Levels*
(Ferozsons, Lahore) ISBN 9789690015723

The following may also be useful:

Biological Sciences Review
(Philip Allan Updates, **www.philipallan.co.uk**)

Stewart, A (1995–6) *Lab Notes: Your Up-to-date Guide to Research in Genetics*
(Wellcome Centre for Medical Science, **http://library.wellcome.ac.uk**)

CD-ROM

BIOSCOPE biological microscope simulation (2004 edition)
This includes 56 slide sets of plant and animal specimens, with features that give the feeling of a real microscope. The slides are accompanied by paper-based tasks (in Word and PDF format), each lasting 45 to 60 minutes. The slide set and tasks meet the needs of the Biology AS and A Level syllabus and include learning to use an eyepiece graticule and a stage micrometer scale.
(Cambridge-Hitachi, **http://www.cambridge-hitachi.com**) ISBN 9781845650261

Experiment Simulator (2005 edition)
This was developed by Cambridge Assessment and provides six simulated science experiments to inspire and support students, based on real experimental data. It includes student worksheets and teacher notes.
(Cambridge-Hitachi, **http://www.cambridge-hitachi.com**) ISBN 9781845651404

Biozone (2005) *Teacher Resource Handbook*
(Biozone Learning Media (UK) Ltd, **www.biozone.co.uk**)

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7.4 Mathematical requirements

At AS, candidates should be able to:

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

At A2, candidates should also be able to:

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

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

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

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

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

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

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

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

Key to symbols

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

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

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

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

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

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7.6 Glossary of terms

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

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

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

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

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

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11. (a) *Suggest*: this may imply that there is no single correct answer (for example, in biology, there are a number of factors that might limit the rate of photosynthesis in a plant in a glasshouse).
    (b) *Suggest*: this may also imply that the candidate must apply their general knowledge and understanding of biology to a 'novel' situation, one that may not formally be 'in the syllabus'. Many data-response and problem-solving questions are of this type.
12. *Find*: a general term that can be interpreted as *calculate*, *measure*, *determine*, etc.
13. *Calculate*: a numerical answer is required. In general, working should be shown, especially where two or more steps are involved. The candidate should give suitable units where possible.
14. *Measure*: this implies that a suitable measuring instrument will give the quantity in question: for example, length, using a rule, or mass, using a balance. The candidate should give suitable units where possible.
15. *Determine*: this often implies that the quantity in question cannot be measured directly but must be found by calculation, placing measured or known values of other quantities into a standard formula. It may also be used when the candidate must carry out a procedure to find a numerical answer. For example, the candidate might be asked to find the energy absorbed by a plant and calculate its efficiency.
16. *Estimate*: the candidate should give a reasoned order of magnitude statement or calculation of the quantity in question, making any necessary simplifying assumptions about points of principle and about the values of quantities not otherwise included in the question.
17. *Show*: the candidate must make an algebraic deduction to prove a given equation. The candidate must make sure to state clearly the terms being used.
18. (a) *Sketch, when applied to graph work*: this implies that the shape and/or position of the curve only needs to be qualitatively correct. However, the candidate should be aware that, depending on the context, some quantitative aspects may be looked for, such as passing through the origin or having an intercept, asymptote or discontinuity at a particular value. On a sketch graph, the candidate must show clearly what is being plotted on each axis.
    (b) S*ketch when applied to diagrams*: this implies that simple, freehand drawing is allowed. However, the candidate should take care over proportions and should show important details clearly.
19. *Compare*: the candidate must give **both** the similarities and differences between things or concepts.
20. *Recognise*: the candidate should identify facts, characteristics or concepts that are relevant and/or appropriate to understanding a situation, event, process or phenomenon.
21. *Classify*: the candidate should group things based on common characteristics.

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

8. Additional information

8.1 Guided learning hours

Advanced Level ('A Level') syllabuses are designed on the assumption that candidates have about 360 guided learning hours per subject over the duration of the course. Advanced Subsidiary Level ('AS Level') syllabuses are designed on the assumption that candidates have about 180 guided learning hours per subject over the duration of the course. ('Guided learning hours' include direct teaching and any other supervised or directed study time. They do not include private study by the candidate.)

However, these figures are for guidance only, and the number of hours required may vary according to local curricular practice and the candidates' prior experience of the subject.

8.2 Recommended prior learning

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

8.3 Progression

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

Cambridge International AS Level Biology constitutes the first half of the Cambridge International A Level course in Biology and therefore provides a suitable foundation for the study of Biology at A Level and thence 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.

8.4 Component codes

Because of local variations, in some cases component codes will be different in instructions about making entries for examinations and timetables from those printed in this syllabus, but the component names will be unchanged to make identification straightforward.

8. Additional information

8.5 Grading and reporting

A Level results are shown by one of the grades A*, A, B, C, D or E indicating the standard achieved, Grade A* being the highest and Grade E the lowest. 'Ungraded' indicates that the candidate has failed to reach the standard required for a pass at either A Level or AS Level. 'Ungraded' will be reported on the statement of results but not on the certificate.

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

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

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

Percentage uniform marks are also provided on each candidate's Statement of Results to supplement their grade for a syllabus. They are determined in this way:

- A candidate who obtains…
  - … the minimum mark necessary for a Grade A* obtains a percentage uniform mark of 90%.
  - … the minimum mark necessary for a Grade A obtains a percentage uniform mark of 80%.
  - … the minimum mark necessary for a Grade B obtains a percentage uniform mark of 70%.
  - … the minimum mark necessary for a Grade C obtains a percentage uniform mark of 60%.
  - … the minimum mark necessary for a Grade D obtains a percentage uniform mark of 50%.
  - … the minimum mark necessary for a Grade E obtains a percentage uniform mark of 40%.
  - … no marks receives a percentage uniform mark of 0%.

Candidates whose mark is none of the above receive a percentage mark in between those stated according to the position of their mark in relation to the grade 'thresholds' (i.e. the minimum mark for obtaining a grade). For example, a candidate whose mark is halfway between the minimum for a Grade C and the minimum for a Grade D (and whose grade is therefore D) receives a percentage uniform mark of 55%.

The uniform percentage mark is stated at syllabus level only. It is not the same as the 'raw' mark obtained by the candidate, since it depends on the position of the grade thresholds (which may vary from one session to another and from one subject to another) and it has been turned into a percentage.

8. Additional information

AS Level results are shown by one of the grades a, b, c, d or e indicating the standard achieved, Grade a being the highest and Grade e the lowest. 'Ungraded' indicates that the candidate has failed to reach the standard required for a pass at AS Level. 'Ungraded' will be reported on the statement of results but not on the certificate.

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

The content and difficulty of an AS Level examination is equivalent to the first half of a corresponding A Level.

Percentage uniform marks are also provided on each candidate's Statement of Results to supplement their grade for a syllabus. They are determined in this way:

- A candidate who obtains…
  - … the minimum mark necessary for a Grade a obtains a percentage uniform mark of 80%.
  - … the minimum mark necessary for a Grade b obtains a percentage uniform mark of 70%.
  - … the minimum mark necessary for a Grade c obtains a percentage uniform mark of 60%.
  - … the minimum mark necessary for a Grade d obtains a percentage uniform mark of 50%.
  - … the minimum mark necessary for a Grade e obtains a percentage uniform mark of 40%.
  - … no marks receives a percentage uniform mark of 0%.

Candidates whose mark is none of the above receive a percentage mark in between those stated according to the position of their mark in relation to the grade 'thresholds' (i.e. the minimum mark for obtaining a grade). For example, a candidate whose mark is halfway between the minimum for a Grade c and the minimum for a Grade d (and whose grade is therefore d) receives a percentage uniform mark of 55%.

The uniform percentage mark is stated at syllabus level only. It is not the same as the 'raw' mark obtained by the candidate, since it depends on the position of the grade thresholds (which may vary from one session to another and from one subject to another) and it has been turned into a percentage.

8. Additional information

8.6 Resources

Copies of syllabuses, the most recent question papers and Principal Examiners' reports are available on the Syllabus and Support Materials CD-ROM, which is sent to all CIE Centres.

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

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

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