General Certificate of Education (International)
Advanced Level and Advanced Subsidiary Level

Syllabus

BIOLOGY 9700

For examination in June and November 2010

BIOLOGY

GCE Advanced Subsidiary Level and

GCE Advanced Level 9700

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Notes

Attention is drawn to the small number of alterations in the syllabus by black vertical lines on either side of the text.

INTRODUCTION

This syllabus is designed to give flexibility both to teachers and to candidates and to place greater emphasis on the understanding and application of scientific concepts and principles than on the recall of factual material, whilst still giving a thorough introduction to the study of Biology.

Centres and candidates may choose:

- to take all Advanced Level components in the same examination 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 examination session. Subject to satisfactory performance such candidates are then only required to take the final part of the assessment (referred to in this syllabus as A2) leading to the full A Level;
- to take the Advanced Subsidiary (AS) qualification only.

AIMS

These are not listed in order of priority.

The aims of a course based on this syllabus should be to:

1. provide, through well-designed studies of experimental and practical biological science, a worthwhile educational experience for all students, whether or not they go on to study science beyond this level and, in particular, to enable them to acquire sufficient understanding and knowledge to

    1.1 become confident citizens in a technological world and able to take or develop an informed interest in matters of scientific import;
    1.2 recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life;
    1.3 be suitably prepared for studies beyond A Level in biological sciences, in further or higher education, and for professional courses.

2. develop abilities and skills that

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

3. develop attitudes relevant to biological science such as

    3.1 concern for accuracy and precision;
    3.2 objectivity;
    3.3 integrity;
    3.4 the skills of enquiry;
    3.5 initiative;
    3.6 inventiveness.

4. stimulate interest in, and care for, the local and global environment, and understand the need for conservation.

5. promote an awareness

   5.1 that scientific theories and methods have developed, and continue to do so, as a result of co-operative activities of groups and individuals and that biological science transcends national boundaries;

   5.2 that the study and practice of Biology are subject to social, economic, technological, ethical and cultural influences and limitations;

   5.3 that the implications of biological science may be both beneficial and detrimental to the individual, the community and the environment;

   5.4 of the importance of the use of IT for communication, as an aid to experiments and as a tool for the interpretation of experimental and theoretical results.

6. stimulate students and create a sustained interest in Biology so that the study of the subject is enjoyable and satisfying.

A Level Biology places considerable emphasis on understanding and use of scientific ideas and principles in a variety of situation, including those which are well-known to the learner and those which are new to them. It is anticipated that programmes of study based on this syllabus will feature a variety of learning experiences designed to enhance the development of skill and comprehension. This approach will focus teachers and learners on development of transferable life-long skills relevant to the increasingly technological environment in which people find themselves. It will also prepare candidates for an assessment that will, within familiar and unfamiliar contexts, test expertise, understanding and insight.

ASSESSMENT OBJECTIVES

These describe the knowledge, skills and abilities that candidates are expected to demonstrate at the end of the course. The Assessment Objectives reflect those aspects of the aims that will be assessed.

A Knowledge with understanding

Students should be able to demonstrate knowledge and understanding in relation to:

1. scientific phenomena, facts, laws, definitions, concepts, theories;
2. scientific vocabulary, terminology, 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.

The syllabus content defines the factual material that candidates need to recall and explain. Questions testing the objectives above 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.)

B Handling information and solving problems

Students should be able, using oral, written, symbolic, graphical and numerical forms of presentation, 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, draw inferences and report conclusions;
5. present reasoned explanations for phenomena, patterns and relationships;
6. make predictions and put forward hypotheses;
7. apply knowledge, including principles, to novel 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 precisely specified in the syllabus content because questions testing such skills are often based on information that is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts that are within the syllabus and apply them in a logical, reasoned or deductive manner to a novel 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.)

C Experimental skills and investigations

Students 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, evaluate and report on observations and experimental data;
5. evaluate information, make predictions and put forward and evaluate hypotheses;
6. identify problems, design, plan and carry out experiments and investigations;
7. select appropriate techniques, apparatus, measuring devices and materials;
8. evaluate methods and techniques, and suggest possible improvements.

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

SCHEME OF ASSESSMENT

Paper	Type of Paper	Duration	Marks	Weighting	
				AS Level	A Level
1	Multiple-choice	1 h	40	31%	15%
2	AS structured questions	1 h 15 min	60	46%	23%
31/32	Advanced Practical Skills	2 h	40	23%	12%
4	A2 structured questions	2 h	100		38%
5	Planning, Analysis and Evaluation	1 h 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.

Paper 2

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

Paper 31/Paper 32

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. 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 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.)

Combinations of papers

- Candidates for Advanced Subsidiary (AS) certification will take Papers 1, 2 and 31/32 at a single examination session.
- Candidates who, having received AS certification, wish to continue their studies to the full Advanced Level qualification may carry their AS marks forward and take just Papers 4 and 5 in the examination session in which they require certification.
- Candidates taking the complete Advanced Level qualification at the end of the course take all five papers in a single examination 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.

WEIGHTING OF ASSESSMENT OBJECTIVES

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

This gives a general idea of the allocation of marks to assessment objectives A and B in the theory papers. However, the balance on each paper may vary slightly. Fifteen percent of the total marks will be awarded for awareness of the social, economic, environmental and technological implications and applications of Biology. These will be awarded within the 'Knowledge with understanding' and the 'Handling information and solving problems' categories.

Teachers should take note that there is a greater weighting of 55% for skills (including handling information, solving problems, practical, experimental and investigative skills), compared to the 45% for knowledge and understanding. Teacher's schemes of work and the sequence of learning activities should reflect this balance, so that the aims of the syllabus may be met, and the candidates prepared for the assessment.

Additional Information

Modern Biological Sciences draw extensively on concepts from the physical sciences. It is desirable, therefore, that by the end of the course, candidates should have a knowledge of the following topics, sufficient to aid understanding of biological systems, but **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

Mathematical and Statistical Requirements are laid out later in the syllabus

Symbols, Signs and Abbreviations

Wherever symbols, signs and abbreviations are used in examination papers, follow the recommendations made in the Institute of Biology publication *Biological Nomenclature, Standard terms and expressions used in the teaching of biology* (3rd Edition 2000). Where no relevant guidance is given in this document, then the ASE publication *SI Units, Signs, Symbols and Abbreviations* (1981) will be followed, except where the guidance has been superseded by *Signs, Symbols and Systematics: The ASE Companion to 16-19 Science* (2000).

STRUCTURE OF THE SYLLABUS

The Subject Content of the syllabus is divided into an AS and A2. The A2 includes a core and an Applications of Biology section, which is studied, in its entirety, by all A2 candidates.

The subject content for the Core and the Applications syllabuses is presented as learning outcomes. The examination will assess the candidate's knowledge and understanding of these.

This structure is shown below.

1 The Core syllabus – there are sixteen sections.

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 twenty one sections, A to U.

- 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**

Applications of Biology

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

Papers 1 and 2 will assess the AS parts of the Core. Paper 4 will assess the A2 parts of the Core and Applications of Biology.

The A2 parts of the syllabus, which will be examined only in the full Advanced Level qualification, are indicated in **bold** type in the subject content.

The Applications of Biology section occupies about 12% of the full Advanced Level course. A booklet covering this section can be purchased from CIE.

In order to 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 is specified by a brief **Contents** section followed by detailed **Learning Outcomes**. It is hoped that this format will be helpful to teachers and students. It must be emphasised that the syllabus is not intended to be used as a teaching syllabus, nor is it intended to represent a teaching order.

It is hoped that teachers will incorporate the social, environmental, economic and technological aspects of Biology wherever possible throughout the syllabus (see **Aims** 4 and 5). Some examples are included in the syllabus and students should be encouraged to apply the principles of these examples to other situations introduced in the course. Inclusion of further examples in the syllabus has been resisted as this would merely increase the amount of factual recall required of students.

Aim 5.4 emphasises the importance of Information Technology in this Biology course. It is hoped that students will make full use of IT techniques in their practical work. Teachers may also use IT in demonstrations and simulations.

Everything that we know about Biology has been learned through practical investigation. Practical work is also motivating and interesting for learners, and can aid in understanding of abstract theoretical concepts. It is expected that practical activities will underpin the teaching of the whole syllabus. Asterisks (*) placed by learning outcomes in the syllabus content show parts of the subject that present particular occasions for practical work.

To support Centres in teaching of practical skills, CIE has produced two booklets totalling almost 200 pages. Each contains 30 practical exercises, of which at least 10 are presented in detail, with lesson plans, student worksheets and useful information for teachers and technical support staff. The other 20 are presented in outline, for Centres to develop, learning from the experience. The booklets are:

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

They are available from CIE publications, 1 Hills Road, Cambridge, CB1 2EU, UK, phone +44 (0) 1223 553553, fax +44 (0) 1223 553558, e-mail international@cie.org.uk

SUBJECT CONTENT

It will be assumed that examples to illustrate concepts and content will be drawn from a wide range of organisms.

It is expected that practical activities will underpin the teaching of the whole syllabus. Asterisks (*) placed alongside learning outcomes indicate areas of the syllabus that present opportunities for practical work.

CORE SYLLABUS

The Core content to be studied by AS candidates, sections A to K, is shown in normal type.

The additional Core content to be studied by A Level candidates, sections **L** to **U**, is shown in **bold** type.

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) *use a graticule and stage micrometer 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 membrane systems and organelles – rough and smooth endoplasmic reticula, Golgi apparatus, mitochondria, ribosomes, lysosomes, chloroplasts, plasma/cell surface membrane, nuclear envelope, centrioles, nucleus and nucleolus;

(d) outline the functions of the membrane systems and organelles listed in (c);

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

(f) *draw plan diagrams of tissues (including a transverse section of a dicotyledonous leaf) and calculate the linear magnification of drawings;

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

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

B BIOLOGICAL MOLECULES

Content

The structure of carbohydrates, lipids and proteins and their roles in living organisms

Water and living organisms

Learning Outcomes

Candidates should be able to:

(a) *carry out tests for reducing and non-reducing sugars (including 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) state one role of each of the following inorganic ions in living organisms: calcium, sodium, potassium, magnesium, chloride, nitrate, phosphate;

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

C ENZYMES

Content

Mode of action of enzymes

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) *follow the time course 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) *investigate and explain the effects of temperature, pH, enzyme concentration and substrate concentration on the rate of enzyme-catalysed reactions, and explain these effects;

(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

The fluid mosaic model of membrane structure

The 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 membranes within cells and at the surface of cells;

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

(d) *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 growth, repair and asexual reproduction;

(b) explain the need for the production of genetically identical cells and fine control of replication;

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

(d) *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);

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

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

F GENETIC CONTROL

Content

The structure and replication of DNA

The 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 hydrogen bonding;

(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;

(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) explain that, as enzymes are proteins, their synthesis is controlled by DNA;

(g) 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

The 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) *describe how to investigate experimentally the factors that affect transpiration rate;

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

(e) *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) *describe how the leaves of xerophytic plants are adapted to reduce water loss by transpiration;

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

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

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

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

(n) *describe the structure of red blood cells, phagocytes and lymphocytes and explain the differences between blood, tissue fluid and lymph;

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

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

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

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

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

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

(u) describe the cardiac cycle;

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

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

H GAS EXCHANGE

Content

The respiratory system

Smoking and smoking-related diseases

Learning Outcomes

Candidates should be able to:

(a) *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) *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) explain the terms *tidal volume* and *vital capacity*;

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

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

(h) describe the effects of nicotine and carbon monoxide on the cardiovascular system with reference to atherosclerosis, coronary heart disease and strokes;

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

(j) discuss the problems of cardiovascular disease and the ways in which smoking may affect the risk of developing cardiovascular disease;

(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 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 cholera, malaria, TB and HIV/AIDS;

(c) explain how cholera, malaria, TB and HIV/AIDS are transmitted and assess the importance of these diseases worldwide;

(d) discuss the roles of social, economic and biological factors in the prevention and control of cholera, 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 and tuberculosis;

(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) *recognise phagocytes and lymphocytes under the light microscope;

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

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

(d) distinguish between B- and T-lymphocytes in their mode of action in fighting infection and describe their origin and functions;

(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) *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 photosynthesis to produce complex organic molecules and that the process of respiration allows this energy to be transferred through chemical reactions so that it can be used by living organisms;

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

(f) *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) *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) *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 and metabolic wastes, using water potential terminology;

(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 (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) *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 abscissic 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

The passage of information from parent to offspring

The nature of genes and alleles and their role in determining the phenotype

Monohybrid and dihybrid crosses

Learning Outcomes

Candidates should be able to:

(a) *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) 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.

Applications of Biology

Q BIODIVERSITY AND CONSERVATION

Content

Classification

Conservation issues

Learning Outcomes

Candidates should be able to:

(a) *outline the five kingdom classification to illustrate the diversity of organisms (cross reference 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) *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) *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) *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) *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) *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) *explain how sorghum is adapted to survive in arid environments;

(g) *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:

- **hybridisation leading to polyploidy in wheat**
- **inbreeding and hybridisation in producing vigorous, uniform maize**
- **genetic manipulation to enhance the vitamin A concentration in rice;**

(i) 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) *describe the histology of 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.

DEFINITIONS AND OTHER USEFUL INFORMATION

This contains definitions and factual information to support the teaching, learning and assessment of Biology within this syllabus in the form that the examiners believe best reflects current understanding of biology. This information will be reflected in the setting of the examination papers.

To give a specific example of how this will work, 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 examination question used in the papers to which this syllabus refers. Candidates will be expected to be familiar with the use of these dictionaries rather than others, and would normally be expected to give answers in terms of these dictionaries. If a candidate were to use a different dictionary in an answer to a question, provided that the candidate made it clear to the examiner which dictionary was being used, and provided that the answers were correct, the candidate would be given credit.

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.

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) which is rearranged to give the actual size of an object where the size of the image and magnification are known, A = I/M.

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.

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.

Active transport – the transport of ions through cell membranes using carrier proteins, against a concentration gradient (from regions where they are at lower concentration to regions where they are at higher concentration) using energy from ATP.

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).

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

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

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

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

Transpiration – the process through which water vapour is lost from the aerial parts of plants, occurring due to 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 leaf to the atmosphere.

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

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

Disease – an abnormal condition affecting an organism that reduces the effectiveness of the functions of the organism.

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

Pathogen – a biological agent (e.g. a virus, bacterium, fungus or protoctist) that causes disease. In the case of a pathogen causing human diseases this will have, as part of its structure, proteins that are different to those of the human host and are therefore antigens.

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).

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.
- Simultaneously, there is the start of the primary phase of the adaptive immune system response, in which specific clones of B- 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 immediately the specific antigen is detected again.

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

Self – the products of the body's own genotype which contain proteins (normally, 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 (see below).

Non-self – proteins (normally, see antigen) which contain sequences of amino acids which are not the same as any self proteins and which have the capability to be recognised by immune system cells and to 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.

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).

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.

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 lasts only for a few weeks.

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 (e.g. natural infection with chicken pox, giving long-term protection from this virus).

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

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.

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

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

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.

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 (e.g. rocky shore or sugar cane field).

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

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.

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

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, e.g. a decomposing log, a pond, a meadow, a reef, a forest, or the entire biosphere.

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

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

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

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

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

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

It can be found by experimentation, using a respirometer with and without soda-lime to absorb the carbon dioxide.

It can also be determined theoretically by calculation,

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

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

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).

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.

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) (designated by the chromosome number, its arm, and its place [e.g. 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 and the gene associated with sickle cell anaemia is at locus 11p15.5, chromosome 11, short arm (p), region 15.5]).

Allele – one of two or more alternative nucleotide sequences at a single gene locus, so alleles are variant forms of a gene e.g. the alleles of the ABO blood group gene are found at a locus on chromosome 9, 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 thus have two copies of the gene, which may be the same allele (homozygous), e.g. $I^A\ I^A$, or $I^B\ I^B$ or $I^O\ I^O$, or may be different alleles (heterozygous), e.g. $I^A\ I^B$, or $I^A\ I^O$ or $I^B\ I^O$. The gene for producing the haemoglobin β-polypeptide has a number of alleles, of which two 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.

Dominant –an allele with a phenotype that is expressed even when present with an allele that is recessive to it, e.g. I^A is dominant to I^O so a person with the genotype $I^A\ I^O$ has blood group A since only the dominant allele is expressed.

Recessive – an allele with a phenotype that is not expressed when an allele that is dominant to it is present, e.g. 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, $I^O\ I^O$.

Codominant – alleles that are both expressed if they are present together in a heterozygous person, e.g. alleles I^A and I^B are codominant, so 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.

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

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.

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). Phenotype, when controlled by a small number of alleles of a particular gene, may be genetically determined (e.g. human eye colour) giving rise to **discontinuous variation**, or when controlled by the additive effects of many genes (polygenic), may be affected by the environment as well as genes (e.g. human height) giving rise to **continuous variation.**

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

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.

- The syllabus content is intended to indicate that 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, using abbreviated names of amino acids as shown below.
- The syllabus content is **not** intended to indicate that candidates 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			
		U	C	A	G
1st base	U	UUU Phe UUC Phe UUA Leu UUG Leu	UCU Ser UCC Ser UCA Ser UCG Ser	UAU Tyr UAC Tyr UAA *Stop* UAG *Stop*	UGU Cys UGC Cys UGA *Stop* UGG Trp
	C	CUU Leu CUC Leu CUA Leu CUG Leu	CCU Pro CCC Pro CCA Pro CCG Pro	CAU His CAC His CAA Gln CAG Gln	CGU Arg CGC Arg CGA Arg CGG Arg
	A	AUU Ile AUC Ile AUA Ile AUG Met	ACU Thr ACC Thr ACA Thr ACG Thr	AAU Asn AAC Asn AAA Lys AAG Lys	AGU Ser AGC Ser AGA Arg AGG Arg
	G	GUU Val GUC Val GUA Val GUG Val	GCU Ala GCC Ala GCA Ala GCG Ala	GAU Asp GAC Asp GAA Glu GAG Glu	GGU Gly GGC Gly GGA Gly GGG Gly

The DNA genetic dictionaries available are of two types, depending which strand of DNA is reported. Many researchers and teachers use a dictionary that includes DNA codes which are complementary to the mRNA codons shown above. During transcription, it is this strand that is used as a template to make the mRNA. This is the DNA dictionary that will be used in all CIE publications including this syllabus and the examination questions associated with it. 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 as these terms have become ambiguous.

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.

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, which is continuously supplied with new raw materials and continuously harvested in order to retain the culture in exponential population growth.

PRACTICAL ASSESSMENT

INTRODUCTION

Candidates should be given opportunities for the practice of experimental skills throughout the whole period of their course of study. As a guide, candidates should expect to 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 do during their course should aim to:

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

Candidates' experimental skills will be assessed in Papers 31/32 and 5. In each of these papers, the examiners may not be strictly bound by the subject content of the syllabus in finding contexts for the setting of questions. Within unfamiliar contexts, candidates will be told exactly what to do and how to do it. Within familiar contexts listed in the syllabus, the candidates will be expected to know how to use the techniques. Knowledge of theory and experimental skills will be drawn only 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, drawing and magnification calculations from unfamiliar structures of specimens;
- following instructions to use unfamiliar biochemical procedures.

PAPER 31/32

Paper 31/32 will be a timetabled, laboratory-based practical paper focussing on the following experimental skills:

- manipulation of apparatus;
- presentation of data;
- analysis and evaluation.

Each paper:

- will consist of two or more questions,
- will consist of two approximately equal halves so that Centres can provide microscopes for half of the candidates at a time,
- will include 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 draw appropriate conclusions,
- will require 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,
- will include 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 will be equivalent in the skills assessed and in the level of demand. Each candidate should take one of these papers. Some Centres may wish to divide their candidates so that some are entered for Paper 31 and the others are entered for Paper 32; other Centres may wish to enter all of their candidates for the same paper.

Mark scheme for Paper 31/32

Paper 31/32 will be marked using the generic mark scheme in the table below. The expectations for each mark category are listed in the sections that follow the table.

Skill	***Total marks***	***Breakdown of marks***	
Manipulation, measurement and observation	16 marks	Successful collection of data and observations	8 marks
		Decisions about measurements or observations	8 marks
Presentation of data and observations	12 marks	Recording data and observations	4 marks
		Display of calculation and reasoning	2 marks
		Data layout	6 marks
Analysis, conclusions and evaluation	12 marks	Interpretation of data or observations and identifying sources of error	6 marks
		Drawing conclusions	3 marks
		Suggesting improvements	3 marks

Manipulation, measurement and observation

Successful collection of 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 (X10, sometimes described as 16 mm or 2/3") and high-power (X40, or 4 mm or 1/6") using a microscope with a graticule fitted into the eyepiece.

Decisions about measurements or observations
Candidates should be able to:

- decide how many tests, measurements or observations to perform;
- 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.
- replicate readings or observations as necessary;
- make and record sufficient, 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 a regularly-spaced set of measurements will be appropriate. For other experiments, such as those requiring the peak value of a curved graph to be determined, it may be appropriate for the measurements to be concentrated in one part of the range investigated. Candidates will be expected to be able to identify the most appropriate distribution of values. In qualitative experiments, precise descriptions and comparisons of colour or other observations are expected.

In experiments, such as those involving enzymes:

- initial rate of reaction may be measured (in which case measurements should be conducted as quickly as practicable),
- the rate of reaction might be expected to be constant over several minutes, or colour changes may take several minutes to occur, in which case leaving the experiment to run for as long as possible may be appropriate,
- an end point is being sought, in which case, candidates should expect to run the experiment until the end point is achieved or the time runs out.

Repeated readings of particular quantities are often necessary in biology, where experimental errors and variation in the activity of biological materials are large and an average value would be more representative. Individual readings or observations should be repeated where they appear to be anomalous. It may be necessary for the candidate to decide how many times to let something that is repetitious occur before recording the observation (e.g. in counting the number of bubbles released from a delivery tube).

Marks may be awarded for:

- measured quantitative data in which the values obtained are reasonable,
- qualitative observations consistent with the materials supplied.

It is important that sufficient distinct observations are made, 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.

In 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: allowances will be made where the quality of data is limited by the experimental method required or by the apparatus and materials used. In making such assessments of accuracy, the scatter of points on a graph may be examined, or the candidate's data or observations may be compared with information supplied by the Supervisor or known to the examiners.

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;
- draw up the table before taking readings/making observations, so that candidates can record directly into the table, to avoid the need to copy up their results;
- include in the table of results, if necessary, columns for raw data, for calculated values and for deductions;
- use column headings that include the quantity and the unit (as appropriate) and that conform to accepted scientific conventions;
- record raw readings of a quantity to the same degree of precision and observations to the same level of detail.

As an example of accepted practice in column headings, if the quantity being measured is length in millimetres, then 'length / mm' would be the usual way to write the column heading, but 'length in mm' or 'length (mm)' would be allowed. Headings such as 'length mm' or just 'mm' are not acceptable. The quantity or the unit or both may be written in words or appropriate symbols may be used provided that their meaning is clear and unambiguous in the context. Avoid t, since may be used for time and for temperature. Conventional symbols or abbreviations, such as ATP for adenosine triphosphate or r for radius, may be used without explanation.

In recording data and observations, if one measurement of length in a column of raw data is given to the nearest millimetre, then all the lengths in that column should be given to the nearest millimetre. The degree of precision used should be compatible with the measuring instrument used: it would be inappropriate to record a distance measured on a millimetre scale as '2 cm'. Where the calibration marks on a measuring instrument are widely spaced, it may be appropriate to interpolate between the marks, but where the calibration marks are close together then the reading should be to the nearest calibration mark. See http://www.chemsoc.org/networks/learnnet/RSCmeasurements.htm for more information on measurement.

Observations of qualitative variables such as colour should be recorded in simple language such as 'blue' or 'orange'. Where fine discrimination is required, terms such as 'pale' or 'dark' should be used as well, and comparisons made 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 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 biuret test.

Display 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 calculations are done, all of the key stages in the calculation should be recorded by candidates, so that credit can be given for correctly displaying working even if the final answer is incorrect. Similarly, where observations form the basis for logical deduction (e.g. the concentration of an unknown solution or the identity of an unknown solute), the main steps in making the deduction should be shown. Again, where inductive thought processes are used to build up a general prediction or to support a general theory, from specific observations, the sequence of major steps used should be reported.

Calculated quantities should be given to the same number of significant figures as the measured quantity that has the smallest number of significant figures. For example, if values of time and of volume of gas collected are measured to 1 and 2 significant figures respectively, then the calculated rate should be given to 1 significant figure, but not 2 or more. See http://www.chemsoc.org/networks/learnnet/RSCmeasurements.htm for more information on significant figures.

Data layout

Candidates should be able to:

- choose a suitable and clear method of presenting the data, e.g. tabulations, chart, graph, drawing or mixture of methods of presentation;
- select which variable(s) to plot and plot 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 are expected to present data in the form in which the key points of the data can be most easily visualised:

- 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 allow the graph to be read easily, 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 un-shaded so that errors are small, and use fine, clear, unbroken lines, showing clear outlines of structures.
- 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). Points should be finely drawn with a sharp pencil, but must still be visible. A fine cross or an encircled dot is suitable; a thick pencil blob is not. Often it is obvious that the data fall on a straight line or smooth curve, when a line of best fit or 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 adjacent points should be joined by straight ruled lines in order to represent the data with the minimum of assumptions. 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.

Analysis, conclusions and evaluation

Interpretation of 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;
- determine the gradient of a straight-line graph or tangent to a curve.
- evaluate the effectiveness of control of variables and thus the confidence with which conclusions might be drawn;
- identify the most significant sources of error in an experiment;
- estimate, quantitatively, the uncertainty in quantitative measurements;
- express such uncertainty in a measurement as an actual or percentage error;
- show an understanding of the distinction between systematic errors and random errors.

Descriptions should be precise, giving quotations of figures to support the description, and calculated values where these are appropriate. Unknown values might 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 gradient is to be determined, the points on the line chosen for the calculation should be 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 intrinsic in measuring devices (see http://www.chemistry-react.org/go/Tutorial/Tutorial_4428.html) or in the observer's ability to observe, or in experiments where limitations of the method introduce errors (e.g. 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 $\pm$ 1 mm, or temperature increase = 14 °C $\pm$ 4 °C. Candidates should be able to suggest which of the sources of error described are likely to be systematic errors such as those resulting from thermometers that consistently read 1 °C above actual temperature, or candidates who read volumes to the wrong part of the meniscus, as well as those which are likely to be random errors due to 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 maintained the same across a number of samples, and from this, give an indication of the confidence that they would have in any conclusions drawn.

Drawing conclusions

Candidates should be able to:

- draw 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;
- draw conclusions from interpretations of observations, data and calculated values;
- make scientific explanations of the data, observations and conclusions that they have described, using the skills, knowledge and understanding that they have acquired from study of the AS Biology syllabus.

Hypotheses that are being tested in AS practical papers will be given, although hypothesis formulation is in skill B, and thus may be tested in the theory components. Conclusions may be expressed in terms of support for, or refutation of, hypotheses, or in terms of the straightforward deductions or inductions that, logically, can 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, in which the candidates will be expected to refer to knowledge and understanding gained in their theory part of the course in order to 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 the use of new methods or strategies to investigate the question;
- suggest ways in which to extend the investigation to answer a new question;
- describe such modifications clearly in words or diagrams.

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

Apparatus requirements for Paper 31/32

The apparatus requirements for Paper 31/32 will vary from paper to paper. A complete list of apparatus and materials required for each question will be issued in the Confidential Instructions. The Confidential Instructions should be followed very carefully. If there is any doubt at all how the practical examinations should be set up, it is vital that Centres contact CIE as soon as possible.

To give some variation in the questions set, some novel items or equipment or materials may be required. The list of practical apparatus and materials later in the syllabus gives details of the requirements that are frequently required. Candidates should be accustomed to using these.

PAPER 5

Paper 5 will be a timetabled, written paper focussing on the following higher-order experimental skills:

- planning;
- analysis and evaluation.

This examination paper will not require laboratory facilities.

It should be stressed that candidates cannot be adequately prepared for this paper without extensive laboratory work during their course of study.

In particular, candidates cannot be taught to plan experiments effectively unless, on a number of occasions, they are required:

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

This requires many hours of laboratory-based work, and it also requires careful supervision from teachers to ensure that experiments are performed with due regard to safety.

The paper will consist of two or more questions totalling 30 marks. Candidates will be required to design an experimental investigation of a given problem. Such questions will not be highly structured: candidates will be expected to answer using extended, structured writing, illustrated with appropriate diagrams and tables. Candidates may be asked to express a prediction in the form of a written hypothesis linking independent and dependent variables, or in the form of a graph showing the expected outcome. There will be activities requiring the making of analyses and evaluations and the drawing of conclusions, in which candidates will be given some experimental data. These questions also will not be highly structured: candidates will be expected to decide for themselves the means that should be used to analyse, evaluate and conclude.

Some questions on this paper may be set in areas of Biology that are difficult to investigate experimentally in school laboratories, either because of the cost of equipment, such as colorimeters or large fermenters, or because of restrictions on the availability of samples and materials, such as living individuals of rare species, or radioactive materials to be used as markers. No question will require knowledge of theory or equipment that is beyond the AS and A2 syllabus. Information that candidates are not expected to know, to permit candidates to use the data, will be provided in the examination paper. The amount of information will be limited to ensure that there is ample time for candidates to read and consider the information.

Mark scheme for Paper 5

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

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

Planning

Defining the problem
Candidates should be able to:
- identify the dependent and independent variable in the experiment or investigation;
- express the aim in terms of a prediction or hypothesis, and express this in words and in the form of a predicted graph;
- identify the variables that are to be controlled.

Candidates will be provided with a scenario and background information to set the context within which they are expected to define the problem. They should be able to make use of this information to identify 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 and their knowledge and understanding of the topic under consideration. Candidates may be asked to express their hypothesis in the form of a sketch graph showing the expected outcome. A list of key variables to control in order to test the hypothesis effectively is required, and should include only variables that might be expected to have some effect on the material involved (e.g. temperature), but not those likely to have a trivial effect (e.g. using the same test-tube).

Methods
Candidates should be able to:
- describe the method to be used to vary the independent variable, and the means that they will propose to ensure that they have measured its values accurately;
- describe how the dependent variable is to be measured;
- describe how each of the other key variables is to be controlled;
- explain how any control experiments will be used to verify 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 in the procedure to be followed;
- 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 should be taken to keep risks to a minimum;
- draw up tables for data that they might wish to record;
- describe how the data might be used in order to reach a conclusion.

The overall arrangement should be workable. It should be possible to collect the data required without undue difficulty if the apparatus were assembled as described. Words and labelled diagrams should be used for describing the apparatus and how to use it. The measuring instruments chosen should measure the correct quantity to a suitable precision. Control experiments may 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, where the enzyme is omitted or denatured.

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

- in % (w/v), e.g. 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 and areas where it would be most serious. They should be able to use this to propose appropriate safety precautions specifically related to the risks that they have identified – e.g. they might identify that protease enzyme solutions pose a particular risk to the cornea if they are splashed, and so that the wearing of eye protection would 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 draw conclusions, including, as appropriate, preparation of results tables, proposed graphs to plot, key points to consider in any evaluation of the method and results, and reference back to the hypothesis.

Analysis, conclusions and evaluation

Dealing with data

Candidates should be able to:

- Identify the calculations that are necessary to be able to draw conclusions from provided data, including those designed to assess the level of errors, confidence limits, statistical tests and means of presentation of data;
- Use calculations to enable simplification or explanation of data;
- Use appropriate statistical tests to assess the variability of data or the statistical differences between samples;
- Use tables and graphs to draw attention to the key points in quantitative data, including the variability of data.

Candidates should know how to choose and carry out calculations required for simplifying data and to make it comparable. These calculations might 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. Similarly they should be able to construct suitable graphs displaying the independent variable on the x-axis and dependent variable on the y-axis, and fulfilling the criteria laid out in the Paper 31/32 section above, additionally including confidence limit error bars calculated using standard error.

Candidates should know how to select 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 select and use, when provided with suitable equations, statistical tests designed to find the differences between samples:

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

See **Notes on the Use of Statistics in Biology** before the Glossary at the end of this syllabus.

Evaluation
Candidates should be able to:

- Identify anomalous values in provided data and suggest appropriate means of dealing with such anomalies
- Within familiar contexts, suggest possible explanations for anomalous readings;
- Identify the extent to which provided readings have been adequately replicated, and describe the adequacy of the range of data provided;
- Use provided information to assess the extent to which selected variables have been effectively controlled;
- Use these evaluations and provided information to make informed judgements on the confidence with which conclusions may be drawn;

In a table or graph of data, candidates should be able to identify values which are clearly anomalous, and suggest strategies for dealing with such anomalies, including repeating the experiment or omitting the affected replicate. Where investigations are set in familiar contexts, that it is expected that candidates will have explored during the course (those marked * in the syllabus content), candidates may be asked to suggest possible causes for such anomalies (above and beyond 'investigator error'), and will be rewarded for answers derived from their own experience of problems intrinsic in the particular investigation.

Candidates will be expected to have a knowledge of the advantages of replication of data, and the practical limitations. Candidates will be expected to be able to identify instances where it would have been sensible for the investigator to take readings at lower or higher values of the independent variable in order to give a complete range of values, and also situations where there are gaps in the range that reduce the information that can be provided from the investigation (e.g. around a key turning point).

Candidates may be provided with information that will permit them to assess the extent to which a particular variable have been effectively controlled (e.g. the temperature recorded within each of a number of samples in which it is supposed to be the same).

Candidates should be able to draw together all of this information to make informed judgements about the reliability of the investigation and the confidence with which the hypothesis may be tested.

Conclusions
Candidates should be able to:

- draw conclusions from an investigation, providing a detailed description of the key features of the data and analyses, and considering whether experimental data supports a given hypothesis;
- make detailed scientific explanations of the data and of their conclusions, drawing on 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;

Key points of the raw data, graphical representations of it and statistical test results should be given, including quoting of relevant figures, leading to a clear indication of the strength or weakness of any support for or against the hypothesis, or indeed, its proof or refutation. Detailed scientific explanations form a part of such conclusions and therefore form a part of this higher-order practical skill assessment, in which the candidates will be expected to refer to knowledge and understanding gained in their theory part of the course in order to provide explanations of their practical conclusions, for example making detailed reference to the rate of effective collisions between enzyme molecules and substrates in explaining the conclusions made about an enzyme-related hypothesis.

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

SAFETY IN THE LABORATORY

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

Associations:

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

Websites:

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

Publications:

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

UK Regulations:

Control of Substances Hazardous to Health Regulations (COSHH) 2002,
http://www.opsi.gov.uk/SI/si2002/20022677.htm, a brief guide may be found at,
http://www.hse.gov.uk/pubns/indg136.pdf

LABORATORY EQUIPMENT

The following is a list of basic materials and apparatus which would be found in a well-equipped Biology laboratory. However, the list is by no means exhaustive.

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 are 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 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, e.g. 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 surface 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
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, e.g. solid-edged razor blade/knife/scalpel
Mortars and pestles
Safety spectacles or other suitable eye protection
Microscope and lamp/inbuilt illumination with high and low power objective lenses (1 each or 1 between 2)
Eyepiece graticules and stage micrometers
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
Petri dishes, culture bottles, autoclave
Inoculating wires/bioloops
Haemocytometers
Tape for sealing dishes
Cultures of live yoghurt
Appropriate cultures of microorganisms, e.g. *Escherichia coli, Bacillus subtilis*

Stocks of:
Iodine in potassium iodide solution
Benedict's solution
[**C**] – Biuret reagent/potassium hydroxide and copper sulfate solution
[**F**] – Ethanol (for fats test)
[**F**] – Methylated spirit (extraction of chlorophyll)
Sucrose (use AR for non-reducing sugar test)
Glucose

Starch
[**C**] – Potassium hydroxide
Sodium chloride
Dilute hydrochloric acid
Hydrogencarbonate indicator
Sodium bicarbonate/sodium hydrogencarbonate
Limewater
Distilled/deionised water
Universal Indicator paper and chart
Litmus paper
Eosin/red ink
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. 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 N, P, K 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

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 (e.g. *Erica* or *Ammophila* or local equivalent)
ts stem, ts root and ts leaf of a dicotyledonous mesophyte (e.g. *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*)

RESOURCE LIST

Teachers may find reference to the following books helpful. These titles represent some of the texts available at the time of printing this syllabus. Teachers are encouraged to choose texts for class use which they feel will be of interest to their students and will support their own teaching style. Texts asterisked (*) indicate those more suitable when choice or availability is limited, and which are most suitable for use as a main text by students.

The following book has been endorsed by CIE 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 987 0521703062

This is a new edition, which covers the whole syllabus, including material to support the applications syllabus and statistics.

Other textbooks that will be found helpful

Alma, P J *(1993) Environmental Concerns*
(CUP, www.cambridge.org) ISBN 0521428696

Biozone *(2004) Advanced Biology AS*, *Advanced Biology A2* – Student Resource and Activity Manuals ISBN 1877329215, 1877329223 – Model Answers ISBN 1877329231, 187722924X
(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 0582429463, 0582429455

Boyle, M and Senior, K *(2002) Biology,* Collins Advanced Science
(Collins Educational, www.collinseducation.com) ISBN 0007136005

Cadogan, A and Best, G *(1992) Environment and Ecology*, Biology Advanced Studies
(Nelson Thornes, www.nelsonthornes.com) ISBN 0174482159

Carr, M and Cordell, R *(1993) Biochemistry*, Biology Advanced Studies
(Nelson Thornes, www.nelsonthornes.com) ISBN 0174481969

*Chapman, J L and Reiss, M J *(1998) Ecology Principles and Applications* (2nd ed)
(CUP, www.cambridge.org) ISBN 0521588022

Clamp, A *(2001) Synoptic Skills in Advanced Biology*
(Hodder Murray, www.hoddereducation.co.uk) ISBN 0340803223

Clegg, C J and Mackean, D G *(2000) Advanced Biology: Principles and Applications* (2nd ed)
(John Murray, www.johnmurray.co.uk) ISBN 0719576709

Clegg, C J, Mackean, D G, Reynolds, R and Openshaw, P *(1996) Advanced biology study guide*
(John Murray, www.johnmurray.co.uk) ISBN 071955358X

*Jones, M, Fosbery, R and Taylor, D *(2000) Biology 1* Cambridge Advanced Sciences
(CUP, www.cambridge.org) ISBN 052178719X

*Jones, M and Gregory, J *(2001) Biology 2* Cambridge Advanced Sciences
(CUP, www.cambridge.org) ISBN 0521797144

*Jones, M and Jones, G *(1997) Advanced Biology*
(CUP, www.cambridge.org) ISBN 0521484731

Kent, M *(2000) Advanced Biology*
(Oxford University Press, www.oup.co.uk) ISBN 0199141959

King, T J, Reiss, M and Roberts, M *(2001) Practical Advanced Biology*
(Nelson Thornes, www.nelsonthornes.com) ISBN 0174483082

Marieb, E *(2001) Human Anatomy and Physiology* (5th ed)
(Benjamin Cummings, www.aw.com) ISBN 0805349898

Phillips, W D and Chilton, T J *(1994) A-Level Biology* (revised ed)
(Oxford University Press, www.oup.co.uk) ISBN 0199145849

*Roberts, M, Monger, G and Reiss, M *(2000) Advanced Biology*
(Nelson Thornes, www.nelsonthornes.com) ISBN 0174387326

Rowland, M *(1992) Biology* Bath Advanced Science
(Nelson Thornes, www.nelsonthornes.com) ISBN 0174384254

Siddiqui, S A *(1999) Comprehensive Practical Biology for A Levels*
(Ferozsons, Lahore) ISBN 9690015729

*Taylor, D J, Green, N P O, Stout, G W and Soper, R *(1997) Biological Science 1 and 2* (3rd ed)
(CUP, www.cambridge.org) ISBN 0521561787

*Taylor, D *(1989) Human Physical Health* Cambridge Social Biology Topics
(CUP, www.cambridge.org) ISBN 0521313066

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, e-mail international@cie.org.uk

Ratledge, C and Kristiansen, B *(2006) Basic Biotechnology* (3rd ed)
(Cambridge University Press) ISBN 0521549582

Spicer, J *(2006) Biodiversity, A Beginner's Guide*
(Oneworld Publications) ISBN 1851684719

Margulis, L, Schwartz, K and Dolan, M *(1999) Diversity of Life: The Illustrated Guide to the Five Kingdoms* (Jones and Bartlett Publishers) ISBN 0763708623

Many of the books previously used for the discontinued Options syllabus will be found to 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 ed)
(John Murray, www.johnmurray.co.uk) ISBN 0719576709

Jones, M and Jones, G *(1997) Advanced Biology*
(CUP, www.cambridge.org) ISBN 0521484731

Phillips, W D and Chilton, T J *(1994) A-Level Biology* (revised ed)
(Oxford University Press, www.oup.co.uk) ISBN 0199145849

Taylor, D J, Green, N P O, Stout, G W and Soper, R *(1997) Biological Science 1 and 2* (3rd ed)
(CUP, www.cambridge.org) ISBN 0521651787

Taylor, J *(2001) Microorganisms and Biotechnology* (2nd ed) Bath Advanced Science
(Nelson Thornes, www.nelsonthornes.com) ISBN 0174482558

*Lowrie, P and Wells, S *(2000) Microbiology and Biotechnology* (2nd ed) Cambridge Advanced Sciences (CUP, www.cambridge.org) ISBN 0521787238

Austin, C R and Short, R V (eds) *(1984) Hormonal Control of Reproduction*
(CUP, www.cambridge.org) ISBN 0521275946

Avery, R, Cuthill, I, Miller, R and Rowlands, G *(1994) The Five Kingdoms* Biology Advanced Studies (Nelson Thornes, www.nelsonthornes.com) ISBN 0174482299

Baggott, L M *(1997) Human Reproduction* Cambridge Social Biology Topics
(CUP, www.cambridge.org) ISBN 0521469147

*Taylor, D *(2001) Growth, Development and Reproduction* (2nd ed) Cambridge Advanced Sciences
(CUP, www.cambridge.org) ISBN 0521787211

Calladine, C and Drew, H *(1997) Understanding DNA* (2nd ed)
(Academic Press, www.apcatalog.com) ISBN 0121550885

Dyson, T *(1994) The Ethics of in Vitro Fertilization*
(Continuum International Publishing – Mowbray) ISBN 0264672836

*Gregory, J *(2000) Applications of Genetics* (2nd ed) Cambridge Advanced Sciences
(CUP, www.cambridge.org) ISBN 0521787254

Hayward, G *(1992) Applied Genetics* Bath Advanced Science
(Nelson Thornes, www.nelsonthornes.com) ISBN 0174385110

Nicholl, D S T *(2002) An Introduction to Genetic Engineering* (2nd ed) Studies in Biology
(CUP, www.cambridge.org) ISBN 0521004713

Vardy, P *(1999) The Puzzle of Ethics*
(Fount) ISBN 0006281443

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, e-mail international@cie.org.uk

Adds, J, Larkcom, E, Miller, R and Sutton, R *(2001) Tools, Techniques and Assessment in Biology*
(Nelson Thornes Ltd) ISBN 0174482736

Hayward, D *(2003) Teaching and Assessing Practical Skills in Science* (Cambridge University Press, http://www.cambridge.org/education/international) ISBN 0521753597 (A resource for teachers to support the delivery of the syllabus – written for IGCSE, but useful for AS and A Level)

Indge, B *(2003) Data and Data Handling for AS Level*
(Hodder Murray, www.hoddereducation.co.uk) ISBN 0340856475

King, T, Reiss, M and Roberts, M *(2001) Practical Advanced Biology*
(Nelson Thornes) ISBN 0174483082

Morgan, S *(2002) Practical Work for Biology*
(Hodder & Stoughton, www.hodderheadline.co.uk) ISBN 0340847123

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

Siddiqui, S A *(1999) Comprehensive Practical Biology for A Levels*
(Ferozsons, Lahore) ISBN 9690015729

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 (Edition 2004)
Includes 56 slide sets of plant and animal specimens, with features that give the feeling of a real microscope. Paper-based tasks (in Word and PDF format), each of 45 to 60 minutes duration, accompany the slides. The slide set and tasks meet the needs of the Biology AS and A Level syllabus including skills in using an eyepiece graticule and a stage micrometer scale.
(Cambridge-Hitachi, http://www.cambridge-hitachi.com) ISBN 1845650263

Experiment Simulator (Edition 2005)
Developed by Cambridge Assessment, the new Experiment Simulator CD-ROM provides six simulated science experiments to inspire and support students, based on real experimental data. It includes superb student worksheets and teacher notes.
(Cambridge-Hitachi, http://www.cambridge-hitachi.com) ISBN 1845651405

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

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, 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 justified
- make estimations of the results of calculations (without using a calculator)
- recognise and use ratios
- correctly calculate percentages and express changes or errors as percentages and vice versa
- comprehend and use the symbols <, >, Δ, $\approx$, /, $\propto$, Σ
- calculate areas of right-angled and isosceles triangles, circumference and area of circles, 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
- select 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 the points with straight rules lines and when it is appropriate to use a line of best fit
- choose, by inspection, a straight line which 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 means to obtain the rate of change
- understand and use the prefixes: giga (G), mega (M), kilo (k), micro (μ), and nano (n).

In addition, at A2, candidates should be able to:

- have sufficient understanding of probability to understand genetic ratios
- understand the principles of sampling as applied to biological situations and data
- understand the importance of chance when interpreting data
- use simple statistical tests such as χ^2 test and *t*-test

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 of value to test for the significance of differences between samples. The chi-squared test allows the evaluation of the results of breeding experiments and ecological sampling. Standard error is useful for expressing the reliability of an estimate of the mean, and for putting error bars on graphs. Each of these tests is dealt with fully 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 be given 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
$\sum$ = '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 appreciate the difference between s_n(σ_n) and s_{n-1} (σ_{n-1}). χ^2 tests will only be expected on one row of data. Candidates should have a brief understanding of what is meant by the term *normal distribution* and appreciate levels of significance. (Tables will be provided.)

Questions involving the use of standard deviation, standard error, a *t*-test or a χ^2 test may be set on Papers 4 or 5. Candidates will **not** be expected to calculate all of the steps in these calculations during an examination. Candidates may be given partly completed calculations to finish.

Electronic calculators will be allowed in the examination, subject to the CIE general regulations.

GLOSSARY OF TERMS USED IN BIOLOGY PAPERS

It is hoped that the glossary (which is relevant only to Biology) will prove helpful to candidates as a guide, although it does not cover every command word that might be used in Biology examinations. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context.

1. *Define* (the term(s)…) is intended literally, only a formal statement or equivalent paraphrase being required.
2. *What do you understand by/What is meant by* (the term(s)…) normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.
3. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can readily be obtained 'by inspection'.
4. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified, this should **not** be exceeded.
5. (a) *Explain* 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 leave the examiner in no doubt **why** something happens.

   (b) *Give a reason/Give reasons* is another way of asking candidates to explain **why** something happens.
6. (a) *Describe*, the data or information given in a graph, table or diagram, requires the candidate to state the key points that can be seen in the stimulus material. Where possible, reference should be made to numbers drawn from the stimulus material.

   (b) *Describe*, a process, requires the candidate to give a step by step written statement of what happens during the process.

   Describe and *explain* may be coupled, as may *state* and *explain*.
7. *Discuss* requires the candidate to give a critical account of the points involved in the topic.
8. *Outline* implies that only the essential points are required, without any supporting detail.
9. *Predict* implies that the candidate is **not** expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question.

   Predict also implies a concise answer, with no supporting statement required.
10. *Deduce* is used in a similar way to *predict* except that some supporting statement is required, e.g. reference to a law or principle, or the necessary reasoning is to be included in the answer.
11. (a) *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer (e.g. in Biology, there are a variety of factors that might limit the rate of photosynthesis in a plant in a glasshouse),

    (b) *Suggest* may also be used to imply that candidates are expected to apply their general knowledge and understanding of biology to a 'novel' situation, one that may be formally 'not in the syllabus' – many data response and problem solving questions are of this type.
12. *Find* is a general term that may variously be interpreted as *calculate, measure, determine, etc.*
13. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved. Suitable units should be given where possible.
14. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or mass, using a balance. Suitable units should be given where possible.

15. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula. It may also be used in the context of a procedure that needs to be carried out so that a numerical answer may be obtained. For example it may be necessary to find the energy absorbed by a plant so that its efficiency may be calculated.

16. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.

17. *Show* is used when an algebraic deduction has to be made to prove a given equation. It is important that the terms being used by candidates are stated explicitly.

18.(a) *Sketch, when* applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, *but* candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value. On a sketch graph it is essential that candidates indicate clearly what is being plotted on each axis.

(b) S*ketch* when applied to diagrams, implies that a simple, freehand drawing is acceptable. Nevertheless, care should be taken over proportions and the clear exposition of important details.

19. *Compare* requires candidates to provide **both** the similarities and differences between things or concepts.

20. *Recognise* is often used to identify facts, characteristics or concepts that are critical (relevant/appropriate) to the understanding of a situation, event, process or phenomenon.

21. *Classify* requires candidates to group things based on common characteristics.

In all questions, **the number of marks allocated** are shown on the examination paper and **should be used as a guide by candidates to how much detail to give**. In describing a process the mark allocation should guide the candidate about **how many steps** to include. In explaining why something happens, it guides the candidate **how many reasons** to give, or how much detail to give for each reason.