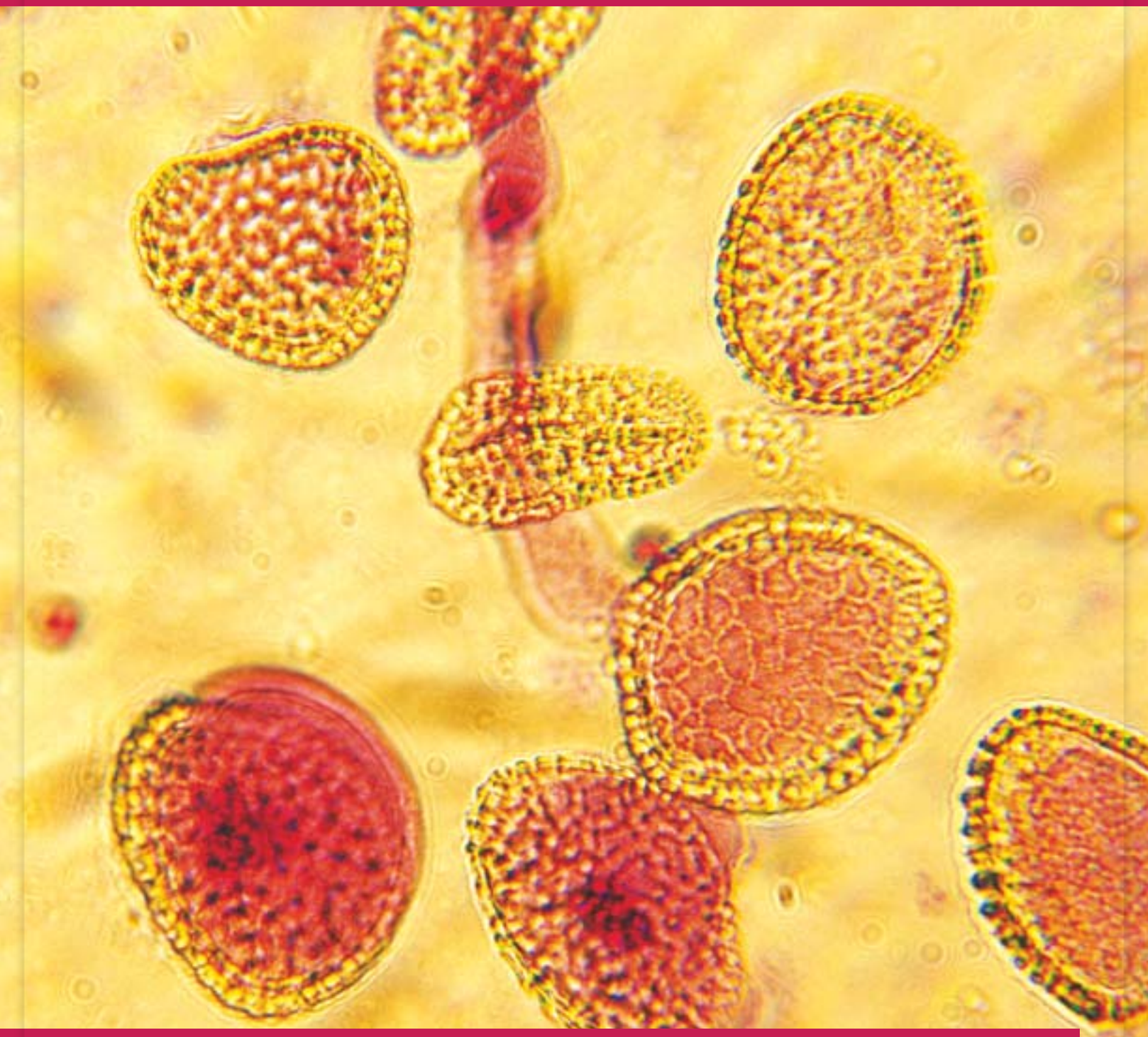
Cambridge Pre-U Syllabus

Cambridge International Level 3 Pre-U Certificate in **BIOLOGY**

For examination in 2010, 2011 and 2012



UNIVERSITY of CAMBRIDGE
International Examinations

Cambridge Pre-U

Biology (9790)

Cambridge International Level 3
Pre-U Certificate in Biology (Principal)

For examination in 2010, 2011 and 2012

QAN 500/3807/2

Support

CIE provides comprehensive support for all its qualifications, including the Cambridge Pre-U. There are resources for teachers and candidates written by experts. CIE also endorses a range of materials from other publishers to give a choice of approach. More information on what is available for this particular syllabus can be found at www.cie.org.uk

Syllabus Updates

This syllabus is for teaching from 2008 and is valid for examination in 2010, 2011 and 2012.

If there are any changes to this syllabus CIE will write to Centres to inform them. This syllabus will also be published annually on the CIE website (www.cie.org.uk/cambridgepreu). The version of the syllabus on the website should always be considered as the definitive version.

Further copies of this, or any other Cambridge Pre-U syllabus, can be obtained by either downloading from our website www.cie.org.uk/cambridgepreu

or contacting:
Customer Services, University of Cambridge International Examinations,
1 Hills Road, Cambridge CB1 2EU
Telephone: +44 (0)1223 553554
Fax: +44 (0)1223 553558
E-mail: international@cie.org.uk

Cambridge International Level 3 Pre-U Certificate

Biology

9790

Contents

Introduction

The Cambridge Pre-U Diploma aims to equip candidates with the skills required to make a success of their subsequent studies at university, involving not only a solid grounding in each specialist subject at an appropriate level, but also the ability to undertake independent and self-directed learning and to think laterally, critically and creatively. The Cambridge Pre-U curriculum is underpinned by a core set of educational principles:

- A programme of study which supports the development of well-informed, open and independent-minded individuals capable of applying their skills to meet the demands of the world as they will find it and over which they may have influence.
- A curriculum which retains the integrity of subject specialisms and which can be efficiently, effectively and reliably assessed, graded and reported to meet the needs of universities.
- A curriculum which is designed to recognise a wide range of individual talents, interests and abilities and which provides the depth and rigour required for a university degree course.
- A curriculum which encourages the acquisition of specific skills and abilities, in particular the skills of problem solving, creativity, critical thinking, team working and effective communication.
- The encouragement of 'deep understanding' in learning – where that deep understanding is likely to involve higher order cognitive activities.
- The development of a perspective which equips young people to understand a range of different cultures and ideas and to respond successfully to the opportunity for international mobility.

All Cambridge Pre-U syllabuses are linear. A candidate taking a Principal Subject must take all the components together at the end of the course in one examination session.

Reflecting the constantly advancing state of scientific knowledge, Cambridge Pre-U Science syllabuses have been designed to allow incorporation of cutting-edge science. Candidates will be able to bring with them, and build on, the knowledge and understanding gained in their 16+ science courses.

Cambridge Pre-U Science syllabuses aim to develop and nurture in candidates a philosophy of evidence-based thinking and instil in them a notion of inquisitiveness and delight in exploring a topic further on their own. The assessments foster practical approaches to problem-solving that engender an appreciation of the need for accuracy and precision when working with data.

The syllabuses are also designed to develop candidates' ability to communicate their understanding, both orally and in written form; to encourage the articulation of informed opinions about science and technology issues, particularly controversial ones; and to enable them to participate in debate about such issues.

In summary, the Cambridge Pre-U Science suite should invoke in candidates a passion for science, and encourage reflection on the nature, history and philosophy of science.

Biology is a subject with a solid foundation based on many decades of research and yet is in the exciting position of having developed at a faster rate in the last 20 years than at any time in its history. Emerging fields such as molecular genetics (e.g. sections 2.2, 6.1), biotechnology (e.g. sections 1.3, 6.1), immunology (e.g. section 2.8) and biological aspects of nanotechnology (e.g. section 1.3) are firmly rooted in the evolutionary paradigm that was set in train by the work of Darwin in the 1800s.

Thus, while most of the Cambridge Pre-U Biology specification is familiar material; biological molecules, protein synthesis, tissues and organs, transport, and so on, one feature that makes it distinctive is the context in which this material should be taught. CIE expects candidates to put biological topics in an evolutionary context, providing an underlying framework to the course. Candidates should expect to develop an understanding of how topics fit into this framework. In other words, they should be able to follow the story of life on Earth.

This syllabus reflects the view shared by many biologists that "*Nothing in Biology makes sense except in the light of evolution*". Theodosius Dobzhansky.

The theories explaining the mechanisms that drive evolution can be covered at any stage during the course: early on for candidates for whom this will give an insightful preparation for the other material; or much later for candidates who will benefit from developing greater maturity before meeting such abstract conceptual material.

The syllabus sequence is not intended to be prescriptive, and is just one of many ways in which this contextual approach could be taught.

This syllabus aims to promote an experience that is exciting for both the learners and teachers, and is thus innovative, stimulating and motivational. It has been constructed with the young 21st century bioscientist in mind. It is expected that a course developed from this syllabus will engender curiosity about and interest in organisms of all kinds. The way that this syllabus is designed will promote the development of courses that enable flexible delivery that could be context-based and candidate-centred, or a more formal, content-based, teacher-led approach, or a convenient combination of these two approaches – in every case incorporating a motivating and engaging mosaic of different learning experiences.

Such variety in delivery will also provide scope for differentiation, encouraging the more self-motivated candidate to explore a topic in greater depth. The syllabus content builds on the candidate's understanding of science, whether this has been gained from separate science GCSEs/IGCSEs or dual award science GCSEs/IGCSEs or other comparable qualifications such as O Level. The organisation of the material means that, if the syllabus order were to be used as a teaching order, conceptual understanding of Biology would build progressively from micro-scale, through to a macro-scale holistic understanding. Of course, teachers are encouraged to devise their own Schemes of Work, which could be context based and which might very well involve a different sequence to meet individual pedagogic preferences and the learning needs of the candidates.

Many candidates, rather than using the scenarios provided, might find it more motivating to develop their own.

The experience of studying Cambridge Pre-U Biology should be an enjoyable and invigorating one for learners of all abilities, providing motivational experiences appropriate to weaker candidates

at the same time as encouraging the most able to develop a far greater breadth of knowledge and understanding.

It has been decided not to include syllabus option choices: Biology is an entirety and compartmentalising it in such a way as to exclude large areas might deconstruct the importance of a synoptic grasp of this vast subject. Much cutting edge science involves some aspect of bioscience. This syllabus offers the opportunity to explore Biology through scenarios, which provides the perfect platform from which to research the new, the exciting and the interesting while still covering the fundamental roots of Biology as prescribed in the content.

The content has been carefully selected to give the full range of fundamental biological science, whilst avoiding potential issues of overload. The intention is to expect the candidate to widen her or his comprehension of the subject as a whole. In examination questions candidates will often be expected to arrive at a solution to a question by means of resorting to their thorough knowledge of first principles. Application of knowledge is the cornerstone to gaining a wider understanding of the subject before specialising; a basic premise of this syllabus.

The model below further explains the thinking underpinning this syllabus, envisaging:

- The opportunity for taking a contextual situation as the point of departure i.e. starting with an application and working towards knowledge and understanding of the underpinning Biology – application-based. For example multicellularity: Why did it originate? When? How? What are the advantages? Why are all organisms not multicellular?
- The opportunity for taking a very different approach, starting with the concepts grounded in knowledge and understanding (K&U) and progressing towards the application/process of contexts – based on fundamentals.
- The opportunity for a mosaic of different teaching and learning opportunities, some of which are application-based and some based on fundamental principles. Thus some areas of Biology may be taught more didactically while other areas of Biology are explored by the learner more independently.

The determinants as to which approach will be employed will depend on the group interest, the teacher's confidence and experience, the available resources, plus the interest value of the topic to the learners.

The Assessment Objectives and assessment model in this syllabus have been adapted to allow appropriate progression from GCSE, IGCSE, O Level and other qualifications of similar level. The amount of material in this syllabus that has already been covered has been minimised. The candidate should herself or himself be expected to revisit areas already covered in previous courses, rather than having these re-taught, taking responsibility for her or his own learning and progress, an important skill.

Key features of this Biology syllabus include:

- Scope for incorporating cutting-edge science into the framework of this syllabus.
- An exciting assessment framework featuring:
    - can-do practical and research tasks which reduce the burden of assessment for the teacher and remove the constraints of assessment criteria on candidates
    - a genuinely worthwhile practical examination to reward candidates who have gained a wide range of laboratory and higher-order practical skills
    - examination questions set in novel contexts

The course develops experimental competence through a series of can-do tasks that target a specified set of skills. Data handling skills involving spreadsheets will be part of the can-do repertoire of first-year skills, which candidates are expected to complete as part of their normal lessons. Teachers simply record that these tasks have been completed. The written practical examination paper will assess some of the skills and analytical techniques in practical scenarios.

The course also gives candidates opportunities to develop their interests and communication skills through researching topics and communicating their findings in presentations, discussions, critical essays, designing learning aids and making posters, flow diagrams and charts. Topics will be chosen by the candidate and teacher in consultation. These are can-do tasks, signed off by the candidate on completion; reducing the burden of assessment for the teacher. They will also encourage creative and able candidates, unhindered by marking criteria, as well as permitting successful completion by weak or very shy candidates.

In addition there is a practical examination designed to reward effective learning of practical skills. The practical examination will offer Centres and candidates a formal assessment model that will encourage the teaching and learning of practical skills as an integrated part of the course. It will make a virtue of the 'plan, obtaining data, analysis and evaluation' model as well as giving a clear incentive to the development of skills of making and presenting observations.

The practical examination has two sections. Section A will require candidates to use a laboratory and will test skills of manipulation, measurement and observation as well as presentation of data and observations. Section B will not require a laboratory and will assess higher order skills of planning as well as analysis, conclusions and evaluation.

The practical examination is assessing an entirely different skill set to the theory components such as Papers 1, 2 and 3. Candidates who develop both sets of skills hand in hand should do well in both theory and practical assessment, but for other candidates, the correlation will be less good. The practical examination is specifically designed to offer a series of high hurdles to reward candidates who have developed skills. It is not designed to discriminate effectively for skilled candidates, but to discriminate those who have not developed those skills.

Prior knowledge and progression

The syllabus builds on the knowledge, understanding and skills typically gained by candidates taking Level 2 (IGCSE, GCSE, O Level) qualifications in Biology, dual award science or additional science. It is recommended that candidates have attained communication and literacy skills at a level equivalent to IGCSE/GCSE/O Level Grade C in English.

The course will equip candidates with a coherent theoretical and practical base of transferable skills and key knowledge suitable for future study and employment in Biology and related fields (e.g. medicine, biochemistry, applied sciences) whilst providing thought-provoking material that may appeal to those who do not wish to pursue a scientific career.

Aims

This Cambridge Pre-U Biology course aims to:

- stimulate and motivate the learner to take responsibility for their learning by pursuing topics beyond the syllabus; progressing towards a broad and deep knowledge and understanding of biology
- allow teachers and candidates some autonomy and flexibility in the delivery mode for this syllabus
- show the importance of Biology in our own lives and in society
- present Biology as a cooperative and cumulative activity, subject to cultural, technological, economic, social and ethical limitations
- stimulate a caring interest in the environment: encompassing the environmental impact of human activities including bioscience and its applications
- develop attitudes relevant to science such as: initiative; inventiveness; objectivity; integrity; the skills of enquiry; concern for accuracy and precision
- provide opportunities for candidates to learn and analyse independently
- provide the tools for candidates to: develop an informed interest in scientific issues; become confident citizens in a technological world; participate in public debate on socio-scientific issues
- develop transferable skills and understanding of the links between Biology, Chemistry and Physics
- instil in candidates safe laboratory practices and equip them with the necessary laboratory skills to pursue the subject further
- promote an awareness of the use and development of scientific models

Assessment Objectives

AO1	**Knowledge with understanding** Candidates will be expected to demonstrate knowledge and understanding in relation to: • biological phenomena, principles, concepts, theories, models, relationships, facts, quantities and definitions • biological science vocabulary, terminology, conventions, symbols and units • Biology laboratory apparatus and methods and their use • the development of Biology through hypotheses, predictions, induction and deduction and through experimental work • the cultural, historical and other contextual influences on developments in Biology • scientific and technological applications of Biology including their social, economic and environmental implications The curriculum content of the syllabus defines the factual knowledge that candidates may be required to recall and explain.
AO2	**Analysis and Application** Candidates will be expected to: • handle and interpret unfamiliar information • select and organise information from a variety of sources • translate information from one form into another • identify patterns, report trends, draw inferences, construct arguments and make conclusions from unfamiliar data • assess the validity of biological information, experiments, inferences and statements • use skills, knowledge and understanding from different areas of Biology to solve problems in unfamiliar situations or to communicate biological information clearly, logically and using appropriate specialist vocabulary or to explain phenomena, patterns trends or relationships This assessment objective relates primarily to unfamiliar data, phenomena or situations which, by definition, cannot be listed in the curriculum content of the syllabus. This assessment objective will be assessed in a variety of contexts, ranging from highly structured explanation, suggestion and comparison responses initiated by stimulus material to much more open-ended discursive opportunities to respond.

AO3	**Practical Skills** Candidates will be expected to: • make predictions and hypotheses • plan investigations • use biological apparatus and techniques skilfully, safely and effectively • make and record observations methodically and with due regard for precision, accuracy and units • manipulate and analyse raw data, including by graphical methods, to identify relationships and use this and other information including suitable statistical tests to draw appropriate conclusions • evaluate methods, techniques and results and suggest improvements to methods • communicate the method and findings of an investigation in a truthful, clear and concise way

Scheme of Assessment

For the Principal Cambridge Pre-U qualification in Biology, candidates take four components in the same session.

Component	Component Name	Duration	Weighting (%)	Type of assessment
	Compulsory Matriculation	n/a	◊	School-based can-do tasks
1	Multiple Choice	1¼ hours	20	Written paper, externally set and marked
2	Structured	1¾ hours	30	Written paper, externally set and marked
3	Long Answer	2½ hours	35	Written paper, externally set and marked
4	Practical*	2½ hours	15	Practical exam, externally set and marked

- *The practical may be sat in two or more separate sessions on the same day, so that centres can divide their cohort – see below.
- ◊ Although there is no weighting associated with the Compulsory Matriculation can-do tasks, these must have been completed in order for CIE to be able to make the Cambridge Pre-U award.

Weighting of Assessment Objectives

	Paper 1 (%)	Paper 2 (%)	Paper 3 (%)	Paper 4 (%)	Whole Assessment (%)
AO1: Knowledge with Understanding	*10*	*16*	*14*	*0*	*40*
AO2: Analysis and Application	*10*	*14*	*21*	*0*	*45*
AO3: Practical Skills	*0*	*0*	*0*	*15*	*15*

Description of Papers

Contexts for questions on written papers

Questions on the written papers will, where possible, be set in novel contexts featuring varied applications of Biology, some of which will be unfamiliar. Contexts may include, for example, pharmaceuticals and medicine, global energy solutions, environmental issues, food, fibre and other material production and preservation, other biotechnologies and aspects of agriculture. Some questions may be set in the context of recent research. Practical, historical and ethical scenarios will be used, including familiar practicals from within the syllabus and unfamiliar practicals as a context for questions that candidates are expected to answer from the practical experiences that they have had. Candidates should be able to leave an examination having learnt something new about Biology and applied it.

Component 1: Multiple Choice

There will be 40 multiple choice questions split into two sections. Section A will have 25 questions and be of the direct choice type.
Section B will have 15 questions with coded combinations of answers: four or more numbered statements where candidates choose one of four combinations which could be correct.
All questions will be based on the whole of the content.

Component 2: Structured

This Structured answer paper will be a single written paper consisting of a number of compulsory structured short-answer questions. All questions will be based on the whole of the content.

Component 3: Long-Answer

The Long-Answer paper will consist of three sections:

- Section A: Data Analysis. This section will have a variable number of questions which will require candidates to solve unstructured scenarios. Questions may ask them to interpret data given in a table, chart or graph. Candidates may be expected to plot, measure and interpret graphs. Candidates will be advised to spend no more than 50 minutes on this section.
- Section B: Comprehension. There will be several structured questions relating to a passage which may be taken or adapted from a scientific journal or book and which will not necessarily relate directly to the content of the syllabus. Questions may ask candidates to explain the meaning of terms used in the passage, rephrase parts of the passage, analyse data in the passage, perform calculations and draw conclusions from what they have read. Candidates will be advised to spend no more than 50 minutes on this section.

- Section C: Synoptic analysis and argumentation. This section, which may include textual or other stimulus material, will consist of a choice of one from a selection of three unstructured questions requiring responses in the form of a discursive essay. Quality of written communication will be given a percentage of the marks available. Candidates should use clear English and will be expected to produce well-structured arguments. Candidates will be advised to spend no more than 50 minutes on this section. Questions in this section may be set on any area of the syllabus, and candidates may wish to use material from many areas of the syllabus within a single answer. Within the Curriculum Content Learning Outcomes, the command word *discuss* indicates topic areas particularly suited to this kind of questioning, where there is an almost infinite variety of potential responses.

Component 4: Practical

This component will consist of a practical examination with a section A and a section B of equal time allocation. Section A will be based in a laboratory and will test skills in measurement, manipulation, observation as well as presentation of data and observations. It will present a series of challenges to test skill development, which a well-prepared candidate should have no difficulty in surmounting. Section B will assess higher-order practical skills of planning, analysis, conclusions and evaluation, and will not require the use of a laboratory. The sections can be taken in either order so that Centres can divide their candidates into two sessions to facilitate management of the laboratory-based part of the examination. Centres may choose to divide up their candidates into more groups if required provided that CIE regulations on the running and security of practical examinations are maintained.

The syllabus makes very clear the skills that are to be developed by the candidates during the course, and thus the skills that will be tested during the examination. Candidates will be expected to have considerable experience of practical work in order to be able to succeed in the tasks set. Well-prepared candidates should succeed in gaining many or all of the marks in this section of this component. The examination will not be of the open-book type and there will not be any pre-release materials for candidates. There will be confidential instructions for Centres which will facilitate the setting up of the examination in an appropriate way.

Compulsory Matriculation

This compulsory, non-certificated component consists of can-do tasks which candidates must complete in order to be eligible to enter the examinations. These can-do tasks also help practise skills later tested in the written examinations. There are two categories of task required:

- **Practical tasks**: Practical work, which should be distributed throughout the learning time available, will cover a full range of skills. The number and nature of the practical tasks required to cover the full range of skills is at the discretion of the teacher.
- **Communication tasks**: Candidates will research the topics set at the end of each of the sections of the syllabus content. During the Principal course, candidates should have the opportunity to work on at least three different tasks from:
    - a group presentation
    - preparing for and running a seminar
    - writing a critical essay
    - creating and presenting a learning aid
    - preparing a synoptic flow-chart or concept map

At least one of the communication tasks should include the use of IT based presentation packages of the PowerPoint® type. These tasks may be taken at any time during the course.

A record of the work should be kept. This may be in the form of a recording of a presentation, or the candidate's notes/slides, or the learning aid, essay, flow-chart or concept map. Teachers are not required to make judgements on the standard of the work. From time to time, CIE may require Centres to provide evidence that these tasks have been completed. If this evidence is not provided then candidates will not be certificated in the written examinations.

Curriculum Content

The sections into which the curriculum content is divided are shown in the table below, emphasising the evolutionary paradigm that underlies the design of the syllabus.

Section 1	**Origin and fundamentals of life**
1.1	**The origin of life**
1.2	**The chemicals of life**
1.3	**The earliest cells and fundamental aspects of cell functioning**
Section 2	**Evolution of the eukaryotic cell**
2.1	**Cell structure and function**
2.2	**Genes and protein synthesis**
2.3	**Cell replication**
2.4	**Evolution of multicellular organisms**
2.5	**Transport systems of multicellular organisms**
2.6	**Nutrition of mammals as example of multicellular organisms**
2.7	**Sensitivity to stimuli in multicellular organisms**
2.8	**Mammalian immunity and monoclonal antibodies**
Section 3	**Energy**
3.1	**ATP**
3.2	**Biochemistry of respiration**
3.3	**Photosynthesis**
Section 4	**Mechanisms of evolution**
4.1	**Meiosis and genetics and the mechanisms of evolutionary change**
4.2	**Reproduction**
Section 5	**Organisms in the environment**
5.1	**Evolutionary and Conservation Ecology**
Section 6	**Biotechnology**
6.1	**Gene Technology**

Cambridge Pre-U Biology places considerable emphasis on understanding and use of scientific ideas and principles in a variety of situations, including those which are new to candidates. As described in the Introduction, it is expected that programmes of study based on this syllabus will feature a variety of teacher-centred and pupil-centred 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 less familiar contexts, test expertise, understanding and insight. A Scheme of Work should be produced by teachers to reflect the sequence and repertoire of learning opportunities that they feel are most appropriate for their candidates.

Teachers should take note of the greater than 50% weighting for skills (including handling information, solving problems, practical, experimental and investigative skills) compared to less than 50% for knowledge and understanding. Teachers' 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.

In the context of the Curriculum Content Learning Outcomes of this syllabus, the following terms will be met and are intended to have meanings as shown in the table below.

Term	Intended meaning
Limited to ...	The list of examples or level of detail given in the syllabus is considered to be sufficient at this level, so that inclusion of further examples or more detail is unlikely to be of benefit to candidates. Question setters will assume that all candidates have studied the topic to the specified level of detail and included the specified examples.
Including ... and e.g. ...	For some individual candidates and cohorts, sufficient examples or details are given to form a coherent understanding without any further exemplification or detail. For other individual candidates or cohorts, there may usefully be the opportunity to pursue the topic to a greater depth. Great care should be taken not to overload the course with content beyond the level that is intended, so that not every opportunity to include more material should be taken. Question setters will assume that all candidates have studied the topic to the specified level of detail and included the specified examples.
... with emphasis on ...	This is an indication that the particular aspects of the topic so described should be the focus of most of the teaching and learning effort, and other aspects should form a smaller part, for example in cell division, where the features of chromosome behaviour that contribute to various outcomes should be studied in more detail than other aspects such as the changes to centrioles and nuclear membrane.
Command words such as state, outline, describe, explain, suggests, compare and discuss ...	A glossary is given at the end of the syllabus that lays out the intended meanings of these terms in the context of the assessment. This glossary will also be of considerable use in helping teachers and candidates determine the intended depth of study of the course.
Command word use	The term use, in the syllabus learning outcomes, points out particular places where candidates will need to apply their understanding of aspects of biology to the solving of problems, for example in genetics.
Details of ... are not required	This is an area where it is considered that inclusion of the material specifically excluded from the syllabus is unlikely to be of benefit to candidates and might prejudice their progress in other areas that are essential to study at this level. Question setters will assume that no candidates have studied the material specifically excluded.

1. ORIGIN AND FUNDAMENTALS OF LIFE

Some teaching cohorts might prefer to raise a number of shorter scenario questions as a more stimulating approach to this section, for example:

- How and why did life get started?
- Why are we so sure about the 'historical fact of evolution' and why are some people not so sure?
- Why is water essential in a living organism?
- How and why do a variety of proteins catalyse such a variety of different reactions so specifically?
- If enzymes denature at 55°C, how do organisms live in hydrothermal vents deep in the ocean or in hot springs at 95°C?

Preamble
In addition to meeting the aims of the syllabus as a whole, this component is intended to develop:

- give an overview of geological timescales and the place of the origin of life in these
- appreciate the significance of key molecules to living organisms
- distinguish between carbohydrate, protein and lipid molecules in terms of elemental composition, structure, intra-molecular bonding and 3-D structure
- recall the function of these molecules in the organism
- understand aspects of prokaryote Biology, and the way in which these are fundamental to the Biology of all living things

Recommended Prior Knowledge
Candidates should have a knowledge of

- KS3 or CIE Checkpoint Science or equivalent
- KS4 5a, 5b, 5c, 6a, 6b, 6c, 6d, 8b, 8c or CIE IGCSE Biology, I1, 2, 3, II1, 2, 3, 4, 5, III3 or equivalent

1.1 The origin of life

Content

geological age of the Earth
water
origin of complex organic molecules

Learning Outcomes
Candidates should be able to:

(a) outline the geological evidence (including the radiometric dating of uranium/lead radioactive decay in zircon from Western Australia) that suggests that the Earth is 4.6 billion years old, and the indirect evidence (including carbon isotope signatures in sedimentary rocks from Greenland) that suggests that life originated as much as 3.9 billion years ago (knowledge of radiometric dating techniques and methods of investigating isotopic signatures will not be required)
(b) describe the chemical and physical properties of water (including: chemical = polarity of water molecules resulting in hydrogen bonding; physical = cohesion, adhesion, high specific heat, heat of vaporisation, comparative density as solid, solvent) and explain the biological significance of these properties
(c) discuss the reasons why water may be considered essential for life as we know it to evolve (limited to the properties listed in 1(b) and the temperature range on planet Earth)
(d) outline the Miller-Urey experiment that showed that complex organic molecules (including amino acids) can spontaneously form from simple inorganic molecules when subjected to the conditions once thought to have prevailed on Earth 4 billion years ago
(e) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

1.2 The chemicals of life

Content

lipids
polysaccharides
proteins
nucleic acids

Learning Outcomes
Candidates should be able to:

(a) describe the structure, and relate this to the properties and functions of: triglycerides and phospholipids
(b) describe the formation of ester bonds such as those found in triglycerides
(c) distinguish between saturated and unsaturated fatty acids
(d) describe the structure, and relate this to the properties and functions of: monosaccharides (α- & β-glucose, fructose and ribose); disaccharides (maltose and sucrose) and polysaccharides (amylose, amylopectin, cellulose and glycogen)
(e) describe the formation of glycosidic bonds
(f) describe the structure, and relate this to the properties and functions of: amino acids; globular proteins (including enzymes and haemoglobin) and fibrous proteins (including keratin and collagen)
(g) describe the formation of peptide bonds
(h) distinguish between the primary, secondary, tertiary and quaternary structure of proteins
(i) explain the role of primary, secondary, tertiary and quaternary structure as well as hydrogen, ionic, peptide and disulphide bonding in giving the shape of 3-D globular proteins

(j) explain the importance of prosthetic groups, with particular reference to haem as a component of haemoglobin and respiratory enzymes (e.g. cytochrome c)
(k) describe the structure of nucleotides to include ATP
(l) describe the condensation of nucleotides to form nucleic acids
(m) describe the structure of DNA and RNA (limited to mRNA and tRNA)
(n) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

1.3 The earliest cells and fundamental aspects of cell functioning

Content

cell membranes
prokaryotic cells
enzymes
fundamentals of cell division and inheritance

Learning Outcomes

Candidates should be able to:

(a) discuss the importance of cell surface membranes in defining cells, as a characteristic of all living things and the extent to which they appear to be essential for life
(b) describe and explain the fluid mosaic model
(c) describe and investigate the factors affecting the permeability and fluidity of membranes (e.g. by investigating the leakage of beetroot cell pigments at a range of temperatures)
(d) explain how and why different substances move across membranes (including simple and facilitated diffusion, osmosis, active transport, endocytosis, exocytosis, phagocytosis)
(e) describe and discuss the fossil evidence (including fossil stromatolites and fossil cyanobacteria from Western Australia and including the existence in rocks of hopane and acyclic isoprenoid molecules derived from the steroids and membrane lipids unique to the cell membranes of prokaryotes) for the origin of prokaryotic cells at least 3.5 billion years ago
(f) outline key structural features of prokaryotic cells (including: unicellular, 1-5 μm diameter, peptidoglycan cell walls, lack of membrane-bound organelles)
(g) outline the structure and functions of prokaryote ribosomes and the structure, function and significance of bacterial cell walls (gram-positive bacteria have cell walls with lots of peptidoglycan – they stain blue with the Gram stain, gram-negative bacteria have less peptidoglycan and have an outer membrane of lipo-polysaccharides which makes pathogenic gram-negative bacteria more dangerous as it may protect against the immune system and antibiotics – they stain red with the Gram stain)
(h) outline the range of metabolic and nutritional diversity in prokaryotes (including photoautotrophs (e.g. cyanobacteria), chemoautotrophs (e.g. deep sea hydrothermal vent bacteria, methanogens, *Rhizobium* and *Sulfolobus*), photoheterotrophs (e.g. ocean planktonic bacteria), and chemoheterotrophs (e.g. saprophytic bacteria in soils) (details of specific metabolic pathways are not required)
(i) explain why enzymes are essential to life
(j) describe the structure and properties of enzymes (to include their role as catalysts in catabolic and anabolic reactions [both intracellular and extracellular] and the roles of intracellular kinase enzymes)
(k) explain the specificity of enzymes and the induced-fit hypothesis

(l) describe, explain and investigate factors affecting rate of enzyme-mediated reactions including the effect of temperature, pH, substrate and enzyme concentration in terms of kinetic energy, successful collisions, complementary shape and fit, as well as active site – substrate interactions including V_{max} as maximum rate of enzyme when saturated with substrate and K_m as the substrate concentration giving ½ V_{max}

(m) describe, explain and investigate competitive (including ethanol as an inhibitor of methanol oxidation) and non-competitive inhibitors (including effect of heavy metal salts on many enzymes),

(n) describe end product inhibition and allosteric modulation (including phosphofructokinase and ATP)

(o) explain and investigate the advantages of enzyme immobilisation

(p) explain and investigate the commercial applications of enzymes including the use of pectinase in the drinks industry

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

(r) explain, in outline, how genetic engineering may be used as a nanotechnology to change the properties of enzymes (limited to the targeted inclusion of additional disulphide bonds in the protease subtilisin in order to enhance its thermostability)

(s) outline the semi-conservative replication of DNA

(t) discuss the scientific method with reference to the contribution of Crick, Watson and Franklin in formulating and testing hypotheses in identification of DNA structure, and the contribution of Meselson and Stahl in revealing, from various plausible possibilities, which theoretical model correctly describes DNA replication

(u) describe gene mutations, limited to substitution, deletion and insertion

(v) briefly outline the mechanism of asexual reproduction by binary fission in a typical prokaryote

(w) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

End of Section 1 synoptic Assessment:

By the end of this section of the course candidates should be able to produce a flow chart or concept map linking one molecule to its macroscopic role or showing a time-line for the Earth and living organisms. Present this to the group as a group presentation, contribution to a class discussion, in the form of group posters or other means, as a synoptic revision exercise.

Practical skills associated with Section 1

Learning Outcomes

Candidates should be able to:

(i) investigate some of the key physical and chemical properties of water

(ii) simulate or investigate the Miller-Urey experiment

(iii) recognise monomers and polymers of carbohydrates, proteins, lipids and nucleic acids from structural formulae and models

(iv) perform biochemical tests to identify types of molecules (including reducing and non-reducing sugars, starch, lipids and proteins) present in a variety of biological materials

(v) investigate the energy content of carbohydrates, lipids and proteins, using simple calorimetry

(vi) investigate the movement of materials through cell membranes, for example by diffusion and osmosis
(vii) investigate gram staining of bacterial cell walls
(viii) investigate the metabolic diversity of bacteria by setting up and monitoring sealed glass columns containing sediment from a pond and water (Winogradsky columns see http://www.personal.psu.edu/faculty/j/e/jel5/biofilms/winogradsky.html)
(ix) carry out investigations into the properties of a variety of enzymes in relation to the effect of temperature, pH, concentrations of enzyme and substrate and inhibitors
(x) investigate the effect of immobilisation of enzymes on re-use of enzymes, ease of removal of enzyme from product and thermostability of enzymes
(xi) investigate the effect of pectinase on clarity of fruit juices
(xii) carry out other relevant practical and research activities

2. EVOLUTION OF THE EUKARYOTIC CELL

Some teaching cohorts might prefer to raise a number of shorter scenario questions as a more stimulating approach to this section, for example:

- What makes eukaryotes different from prokaryotes?
- Are eukaryotes more successful than prokaryotes?
- What are the advantages and disadvantages of using electron microscopes?
- How can I determine what is inside a cell and what the parts do?
- How are intracellular structures adapted to their functions?
- How do eukaryotic cells replicate?

Preamble
In addition to meeting the aims of the syllabus as a whole, this component is intended to develop:

- an understanding of the fundamental concepts associated with Biology at the eukaryote level
- an ability to recognise and identify organelles under the microscope or from photomicrographs
- an understanding of the structure of an organelle and how to relate this to its function
- understanding of aspects of the physiology of multicellular organisms

Recommended Prior Knowledge
Candidates should have a knowledge of

- KS3 or CIE Checkpoint Science or equivalent
- KS4 5a, 5b, 5c, 5c, 5d, 6a, 6b, 6c, 6d, 8b, 8c or CIE IGCSE Biology, I1, 2, 3, II1, 2, 3, 4, 5, 6, 7, 9, 10, III3 or equivalent

2.1 Cell structure and function (4 weeks)

Content

evolution and origin of eukaryotic cells
microscopy
organelles: structure and function

Learning Outcomes

Candidates should be able to:

(a) describe the evidence (including the existence in rocks of complex sterane molecules derived from the cholesterol unique to the cell membranes of eukaryotes) that suggests that eukaryotes originated about 2.7 billion years ago

(b) describe and explain the theory of endosymbiosis and the evidence that supports it (limited to mitochondria and chloroplasts, and including: are similar size to modern prokaryotes, have the same sized ribosomes, have inner membranes very similar to modern prokaryotes, split by a process similar to binary fission, contain their own circular DNA that is not associated with protein, and may also be sensitive to some antibiotics like prokaryotes)

(c) discuss the importance of internal membranes in permitting larger cells, including compartmentalisation and increased surface area of energy releasing reactions (with reference to mitochondria)

(d) recognise the following cell organelles and outline their functions

- nucleus
- nuclear envelope
- nucleolus
- rough and smooth endoplasmic reticulum
- eukaryote ribosomes
- Golgi apparatus
- lysosomes
- secretory vesicles
- mitochondria
- chloroplasts
- vacuoles
- cell walls
- centrioles

(e) discuss the advantages (including permitting movement and phagocytosis) and disadvantages (loss of water potential stability and need for osmoregulatory organelle or organ) of loss of cell wall during evolution of animal cells

(f) explain why classification systems are used to categorise organisms

(g) explain why phylogenetic classifications are more useful than an artificial classification for making sense of the diversity and number of types of organism (including: relationship to simple evolutionary timelines and patterns of DNA variation, efficiency of storage and retrieval of information, predictive value from features and DNA sequences common to related organisms)
(h) discuss the merits of 5 Kingdom and 3 Domain classification systems (limited to utility and phylogenetic validity)
(i) explain the difficulties in including viruses in classifications of organisms
(j) explain the mode of action of penicillin on bacteria (as an example of an antibiotic) and explain why penicillin does not affect viruses
(k) explain the relative advantages of light and electron microscopes (including the theoretical explanations for these)
(l) explain and distinguish between resolution and magnification with reference to light microscopy and electron microscopy,
(m) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

2.2 Genes and protein synthesis

Content

the gene and genetic code
protein synthesis
introns
control of gene expression

Learning Outcomes

Candidates should be able to:

(a) define a gene as an ordered sequence of nucleotides located at a particular locus on a particular chromosome which codes for a particular protein, or in certain cases a functional or structural RNA molecule. Discuss the limitations of this definition with reference to introns, exons and promoters
(b) discuss the impact of the Human Genome Project on our understanding of the size of the human genome (including reference to the number of human proteins and genes and non-coding DNA)
(c) describe the genetic code and discuss the extent to which it is true that the code is universal to all organisms and the significance of that near universality
(d) explain protein synthesis in terms of transcription and translation including the roles of DNA, mRNA, tRNA and ribosomes
(e) describe, in outline, eukaryotic introns, exons and splicing and discuss potential reasons for the existence of introns limited to views that they might be evolutionary relicts or that they might have important regulatory and error-checking functions
(f) explain, in outline, how the greater organisation of eukaryotic DNA, permitted by associated histone proteins, means that eukaryotic gene control sequences can be located at much greater distances away from the gene
(g) describe, in outline, the control of gene expression (limited to the lac operon as a example of the way in which environmental control of expression and control of a group of functionally related genes by a single controller, occur in prokaryotes)

(h) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

2.3 Cell replication

Content

DNA replication
mitosis
differentiation and specialisation

Learning Outcomes

Candidates should be able to:

(a) outline mechanisms of asexual reproduction in living organisms (e.g. binary fission in *Bacillus*, multiple fission in *Plasmodium*, budding in *Saccharomyces*, runner formation in *Fragaria* and parthenogenesis in *Aphis*)
(b) outline the mitotic cell cycle including growth, DNA replication, mitosis and cytokinesis as well as the relationship of the cell cycle with apoptosis
(c) state that mitosis is controlled by the interaction of extracellular growth factors that control genes which produce intracellular kinase proteins (see 1.3j)
(d) describe and explain mitosis, with the aid of diagrams, in terms of chromosome, nuclear envelope and centriole behaviour with emphasis on the features of chromosome behaviour that contribute to the production of cells that are genetically identical to each other and to their predecessor
(e) describe how the length of telomeres determines the number of divisions of a cell by mitosis (limited to the shrinkage of telomeres at each replication since DNA cannot replicate right to the end [the end replication problem – of which no details are required] and the reverse transcriptase [TERT] used to reverse the shrinkage in cells that must repeatedly divide throughout life [e.g. cells in the basal layer of skin, stem cells and some white blood cells])
(f) describe how stem cells (zygotic, embryonic and adult) are obtained for research
(g) explain the meaning of the terms totipotency (zygotic cells which have ability to form whole organisms so are also pluripotent and multipotent), pluripotency (embryonic cells which have ability to form any organ or type of cell so are not totipotent but are multipotent) and multipotency (adult stem cells which have ability to form any cell type but are not pluripotent or totipotent) (candidates should be aware that these definitions are not agreed by all scientists)
(h) outline the control and differentiation of stem cells (including gene expression and production of a range of cell types)
(i) discuss the current and potential uses of stem cells (e.g. replace damaged tissues, study aspects of development and cell chemistry, test new drugs, screen potentially toxic chemicals, facilitate gene therapy)
(j) explain that the effects of ionising radiation on living cells can have a range of outcomes including DNA damage which is repaired, DNA damage that cannot be repaired, leading to apoptosis, and DNA damage causing mutations that do not kill the cell but are passed on to its descendents during cell division (including mutations that can cause cancer e.g. those that cause proto-oncogenes to become oncogenes and those that reduce the activity of tumour-suppressor genes)
(k) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

2.4 Evolution of multicellular organisms

Content

evolution of multicellular organisms

Learning Outcomes

Candidates should be able to:

(a) describe and discuss the available evidence that suggests that multicellular eukaryotes originated between 1000 and 600 million years ago (including fossil Vendobionts from 600 mya, the Cambrian Explosion and the Burgess Shale fossils at 543 mya, and molecular clocks that suggest 700-100 mya)

(b) discuss the reasons why only eukaryotic cells have evolved into multicellular organisms

(c) contrast the modes of nutrition of contemporary multicellular organisms (e.g. *Brassica* and *Rattus*) with non-multicellular eukaryotic cells (e.g. *Saccharomyces* and *Chlorella*) and prokaryotes (e.g. *Bacillus* and purple sulphur bacteria)

(d) discuss the impact of size on surface area/volume ratio and the significance of this for organisms

(e) discuss the advantages and disadvantages of being multicellular limited to division of labour and specialisation, greater control of internal environment, as against, increased complexity and coordination issues, vunerability to trauma

(f) explain the need for mass transport systems in multicellular organisms

(g) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

2.5 Transport systems of multicellular organisms

Content

transport in animals
transport in plants

Learning Outcomes

Candidates should be able to:

(a) discuss the advantages and disadvantages of:

- transport systems driven by evaporation and those driven by energy released by respiration
- open and closed transport systems
- single and double circulatory systems including the increasing complexity and efficiency of circulatory systems of fish, amphibians and mammals

(b) describe the structure, and explain how the structural features relate to the functions, of:

- mammalian arteries, veins and capillaries
- cellular components of mammalian blood (including erythrocytes, platelets, leucocytes – lymphocytes, granulocytes, monocytes)
- the mammalian heart – cardiac cycle including pressure changes in the heart, its electrical coordination and its control by the medulla oblongata in the brain

(c) explain the functions of blood including transport of oxygen and carbon dioxide

(d) explain the significance of oxygen dissociation curves and the Bohr shift
(e) describe the structure and function of the xylem of flowering plants and explain the relationship between its structure and functions
(f) explain the role of cohesion/tension in the transport of water in the xylem
(g) describe the structure and function of phloem tissue and explain the relationship between its structure and function
(h) explain the mass flow model of phloem flow
(i) describe the structure and function of stomata and their guard cells and explain the relationship between structure and function
(j) explain the mechanism of opening and closing of stomata
(k) discuss the stomatal and other adaptations characteristic of species living in a variety of habitats (including hydrophytes and xerophytes)
(l) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

2.6 Nutrition of mammals as an example of multicellular organisms

Content

nutrient requirements and modes of nutrition
mammalian alimentary canal and digestion

Learning Outcomes

Candidates should be able to:

(a) list the nutrient requirements of mammals, energy-providing foods (carbohydrates and fats), growth-promoting foods (proteins), mineral ions (calcium, phosphate, iron and iodine), vitamins (A, $B_{1,2,3,5,6,12}$ and folic acid, C and D) and water including the function of the nutrients in the organism
(b) recall the structure and function of the mammalian alimentary canal including histology of stomach, ileum and pancreas
(c) identify site of production, activation and action of the following enzymes in humans as an example of a mammal: amylase, maltase; pepsin and trypsin as endopeptidases; exopeptidases; lipase
(d) explain the parts played by bile, mucus and sodium hydrogen carbonate in human digestion
(e) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

2.7 Sensitivity to stimuli in mammals as an example of multicellular organisms

Content

muscles, nerves, brain
homeostasis
cell signalling

Learning Outcomes
Candidates should be able to:

(a) describe the organisation of central and peripheral nervous systems to include transverse section of spinal cord
(b) outline the gross anatomy and functions of the brain (limited to the cerebrum (cerebral hemispheres), thalamus, hypothalamus, midbrain, hind brain (to include the medulla oblongata, pons varolii and cerebellum) the pituitary body and cerebro-spinal fluid
(c) explain the possible effects of ageing on the brain in humans (limited to dementia and research into its possible causes, symptoms and treatments including stem cells)
(d) describe the structure and function of sensory and motor neurones
(e) describe the production of the resting potential and the generation and transmission of action potentials in myelinated and unmyelinated neurones
(f) discuss the factors affecting the speed of impulse transmission in neurones (limited to neurone diameter, body temperature and myelination)
(g) explain reception and transduction of stimuli as exemplified by the Pacinian corpuscle
(h) describe and explain transmission at synapses including antagonistic excitatory and inhibitory neurotransmitters as exemplified by acetylcholine, noradrenaline and GABA
(i) describe the structure and functioning of the neuromuscular junction and propagation of the action potential across muscle cells
(j) describe the histology and ultrastructure of striated muscle and relate this to its contraction
(k) describe and explain the sliding filament theory of muscle contraction to include the roles of calcium ions, ATP, actin, myosin and tropomyosin
(l) define homeostasis as the ability to maintain a dynamic equilibrium resulting in a stable internal environment using negative feedback mechanisms.
(m) describe the structure and function of the liver to include its role in blood sugar control, deamination, transamination, detoxification and heat generation
(n) explain the actions of insulin and glucagon on the hepatocyte to include the role of membrane receptors and second messengers as well as membrane permeability to glucose
(o) describe the gross anatomy and histology of the kidney and explain its role in excretion and osmoregulation with reference to ultrafiltration, selective reabsorption and countercurrent multiplier
(p) discuss the role of the hypothalamus, posterior pituitary and ADH in osmoregulation
(q) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

2.8 Mammalian immunity and monoclonal antibodies

Content

structure, function and physiology of the mammalian immune system
monoclonal antibodies

Learning Outcomes
Candidates should be able to:

(a) contrast the specific and non-specific immune systems
(b) outline the role of B-cells, plasma cells, memory cells, helper-T cells and cytotoxic-T cells in giving specific immune primary and secondary responses

(c) discuss the structure and action of antibodies (including variable and non-variable regions of a monomeric immunoglobin (e.g. IgG), but not including the range of types and functions of immunoglobin)
(d) distinguish between active and passive immunity, as well as natural and artificial immunity, limited to specific examples including smallpox, rabies and tetanus
(e) outline the ABO blood group system and discuss its implications in transfusion and hyperacute rejection of transplanted organs
(f) outline the principles involved in histocompatibility and acute transplant rejection (details of the MHC system are not required)
(g) outline the means used to produce monoclonal antibodies and explain why it is necessary to use hybridoma cells for this purpose
(h) discuss and evaluate the use of monoclonal antibodies compared to conventional methods for diagnosis and treatment including pregnancy testing, diagnosis of HIV/AIDS and radioimmunotherapy of cancer
(i) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

End of Section 2 synoptic Assessment:

By the end of the Short Course or Principal part of this section of the course candidates should be able to produce a poster, booklet, audiovisual presentation or other means of communicating information, summarising an aspect of: the origin, diversity or cellular biology of eukaryotic cells or multicellular organisms; the Human Genome Project; protein synthesis; mitosis or the cell cycle; stem cells; or aspects of the physiology of plants or animals. This should be made available to the group and others who are interested, as part of a group display using wall space or audiovisual media as appropriate, as a synoptic revision exercise.

Practical and research skills associated with Section 2

Learning Outcomes
Candidates should be able to:

(i) use a light microscope, stage micrometer scale and eyepiece graticule
(ii) correctly measure, using a light microscope and specimens, the size of objects and calculate their magnification
(iii) produce a drawing of an organism or section through a small organism or a part of an organism as seen under the light microscope
(iv) produce correctly labelled and annotated drawings, from microscopic examination and from electronmicrographs
(v) recognise eukaryote organelles in a variety of cells from across the four eukaryotic kingdoms
(vi) sequence images of eukaryotic cells undergoing mitosis
(vii) prepare and view slides of root tip squashes or other material for mitosis
(viii) investigate the totipotency of plant meristematic / callus cells
(ix) explain the relationship between structure and function of histological specimens from mammalian and plant transport systems including prepared slides of blood, heart, blood vessels, xylem, phloem and stomata with associated cells

(x) explain the relationship between structure and function of histological sections and electronmicrographs of mammalian stomach, ileum, pancreas, spinal cord, brain, nerves, myelinated neurones, Pacinian corpuscles, synapses, neuromuscular junctions, striated muscle, liver, kidney, hypothalamus and pituitary gland
(xi) investigate aspects of examples of homeostasis such as control of heart-rate, pupil diameter, thermal budget or osmoregulation
(xii) investigate the effect of penicillin or other antibiotics on bacterial growth
(xiii) carry out other relevant practical and research activities

3. ENERGY

Some teaching cohorts might prefer to raise a number of shorter scenario questions as a more stimulating approach to this section, for example:

- What is it about ATP that makes it so important?
- How does ATP get made?
- Why is anaerobic respiration so much less efficient at releasing energy from a glucose molecule than aerobic?
- What is photorespiration, why does it happen and how do plants minimise its effect?

Preamble
In addition to meeting the aims of the syllabus as a whole, this component is intended to develop:

- insight into the importance of ATP and the role of chemiosmosis
- understanding of the mechanisms of release of energy through aerobic and anaerobic respiration
- understanding of photosynthesis including the implications of photorespiration

Recommended Prior Knowledge
Candidates should have a knowledge of

- KS3 science or equivalent
- KS4 5a, 5c, 5d, 6a, 6b, 6c, 6d, 7a, 7c or CIE IGCSE Biology, II1, 2, 3, 4, 6, 8, IV1 or equivalent

3.1 ATP

Content

ATP
chemiosmosis

Learning Outcomes
Candidates should be able to:

(a) explain the need to release energy to drive metabolic reactions and role of ATP as 'energy currency'
(b) discuss the significance of ATP being both the universal 'energy currency' and a building block of nucleic acids (in relation to the likelihood that nucleic acid synthesis was one of the first energy-using biological reactions)
(c) state that electrons may gain energy from sunlight or from oxidation of chemical substrates and that this energy may be used to do work
(d) outline chemiosmosis as an almost universal system in prokaryotes and eukaryotes in which:
- energetic electrons pass through the electron transport system to release energy
- the released energy is used to transfer protons out through cell membranes
- as these protons diffuse back through the membrane, their kinetic energy is used in membrane-associated ATP synthase to add phosphate to ADP, forming ATP

(e) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

3.2 Biochemistry of respiration

Content

glycolysis
anaerobic respiration
reactions within mitochondria

Learning Outcomes
Candidates should be able to:

(a) outline glycolysis (phosphorylations to fructose 1,6-diphosphate, hydrolysis to triose phosphate, oxidation and dephosphorylation to pyruvate with the net production of 2 ATP and 2 reduced NAD molecules)
(b) outline anaerobic respiration in animals limited to oxidation of reduced NAD to regenerate NAD and conversion of pyruvate to lactate and at the same level of detail, compare and contrast this with anaerobic respiration in yeast and plants
(c) outline the link reaction and Krebs cycle within the mitochondrion (general principles of dehydrogenation and decarboxylation to produce ATP, and reduced NAD and FAD)
(d) compare and contrast the amount of energy released per molecule of glucose substrate in aerobic and anaerobic respiration and explain the reasons for the difference
(e) explain the effect of end-product inhibition and toxins (e.g. cyanide) on the rate of respiration

(f) outline the aerobic respiration of alternative respiratory substrates (limited to carbohydrates, triglycerides and proteins) to include both theoretical and practical understanding of RQ limited to:

- theoretical calculation of RQ for carbohydrates and triglycerides when presented with the formula in the form $C_xH_yO_z$
- practical determination of RQ for germinating seeds or other organisms in respirometers with and without soda-lime
- the meaning of RQ values between 0.7 and 1.0, and above 1.0 in terms of information about possible respiratory substrates and processes

(g) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

3.3 Photosynthesis

Content

light dependent reactions
light independent reactions

Learning Outcomes

Candidates should be able to:

(a) explain the relationship between the light-dependent and light-independent reactions of photosynthesis within the chloroplast of a C3 plant
(b) use chromatography to identify key photosynthetic pigments (limited to chlorophylls a and b, carotene and xanthophyll) and interpret absorption and action spectrum graphs
(c) explain the distribution of photosynthetic pigments and their function inside the C3 chloroplast
(d) explain the roles of photosystems 1 and 2 and electron transport chain, generation of proton gradient and resultant production of ATP in cyclic and non-cyclic photophosphorylation and reduced NADP
(e) explain the Calvin cycle (RuBP and fixation of carbon dioxide to form GP followed by its reduction to form triose phosphate and regeneration of RuBP)
(f) outline the use of Calvin cycle intermediates to generate a range of organic molecules
(g) discuss the importance of the enzyme rubisco and its vulnerability to competitive inhibition by oxygen during photorespiration in relation to its evolution in a reducing environment
(h) outline the impact of high light intensities and temperatures on the rate of photorespiration
(i) explain, in outline, how C4 and CAM plants reduce the impact of photorespiration by isolating the light-independent reactions from the oxygen in the air (limited to the means used to produce spatial separation [C4] and temporal separation [CAM], biochemical details of the C4 pathway are not required)
(j) explain the global distribution of C3 and C4 plants in terms of evolutionary advantage in tropical and temperate climates and the potential impact of climate change on future patterns of agriculture
(k) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

End of Section 3 synoptic Assessment:

By the end of this section of the course candidates should be able to research and produce an informational outcome such as some kind of presentation or discussion or critical essay or learning aid or poster or flow diagram or chart or other audiovisual means of communicating information. This should be a topic of interest to the candidate from within Section 3, such as: ATP; electron transport systems; biochemistry of respiration or C3 photosynthesis; aspects of respiration of varied substrates; comparison of C3, C4 and CAM plants or other energy-related topics of interest to the individual.

It should be distinct from those used in previous sections of the syllabus so that a balance of can-do skills is demonstrated over the duration of the course. It may be communicated by any appropriate means to the group as a synoptic revision exercise.

Practical and research skills associated with Section 3

Learning Outcomes
Candidates should be able to:

(i) investigate the rate of yeast population growth and glucose respiration in aerobic and anaerobic conditions
(ii) investigate visualisation of mitochondria using, for example, inner epidermis of onion scales or celery tissue stained with Janus green B or web search for fluorescent staining images of mitochondria or prepared slides such as those from Philip Harris showing mitochondria
(iii) investigate RQ using respirometers
(iv) investigate the Hill reaction using a chloroplast suspension and DCPIP.
(v) investigate the structure of chloroplasts using electronmicrographs
(vi) carry out paper or other chromatography to separate and identify key photosynthetic pigments
(vii) investigate absorption of light of different colours by chlorophyll solutions using a colorimeter or a prism
(viii) compare the leaf anatomy of C3 (privet), C4 (maize) and CAM (Crassula) plants under the light microscope
(ix) compare the growth of C3 and C4 seedlings in varied conditions of illumination, temperature and water supply
(x) carry out other relevant practical and research activities

4. MECHANISMS OF EVOLUTION

Some teaching cohorts might prefer to raise a number of shorter scenario questions as a more stimulating approach to this section, for example:

- How are meiosis and genetics connected?
- What are the mechanisms that drive evolutionary change?
- What is the evidence that evolution does explain life in all its richness?
- Why sex?

- What use is knowing about all those hormones?
- Why does classification need to be more complicated than plants and animals?

Preamble
In addition to meeting the aims of the syllabus as a whole, this component is intended to develop:

- understanding of the roles of mutation, meiosis and genetics in producing variation and inheritance
- appreciation of the role of founder effects, genetic drift and natural selection in driving evolutionary change
- understanding of the importance of sexual reproduction and aspects of human reproduction and its control
- awareness of biodiversity and the relationship between classification and evolution

Recommended Prior Knowledge
Candidates should have a knowledge of

- KS3 or CIE Checkpoint Science or equivalent
- KS4 5a, 5b, 5c, 8a, 8b, 8c or CIE IGCSE Biology, I1, 2, 3, II1, 2, 3, IV1, 2, 3, 4, 5 or equivalent

4.1 Meiosis and genetics and the mechanisms of evolutionary change

Content

meiosis
mendelian genetics
mutation and variation
selection and changes in allele frequency
speciation
aspects of evolution

Learning Outcomes
Candidates should be able to:

(a) describe meiosis in terms of chromosome, nuclear envelope and centriole behaviour with emphasis on the features of chromosome behaviour that contribute to reduction division and (through crossing over and independent assortment) to genetic variation (details of stages within prophase 1 are not required)
(b) explain how independent assortment and crossing over can contribute to genetic variation
(c) define and use the terms gene, allele, locus, phenotype, genotype, dominant, recessive and co-dominant
(d) use genetic diagrams to solve dihybrid crosses, including those involving sex linkage, autosomal linkage, epistasis, co-dominance and multiple alleles
(e) use data from breeding experiments involving autosomal linkage to produce simple chromosomal maps

(f) use and interpret chi-squared test to test the significance of the difference between observed and expected results (the formula for the chi-squared equation will be provided)

(g) state, with examples, the differences between continuous and discontinuous variation (limited to relative number of genes and alleles involved and relative impact of the environment as well as relative range of phenotypes)

(h) distinguish between chromosome mutation and gene mutation, including Down's syndrome, sickle cell anaemia and cystic fibrosis

(i) explain, with reference to sickle cell anaemia, how mutation might affect expression of a protein and thus affect phenotype

(j) 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)

(k) discuss the roles of genetic screening for genetic conditions and the need for genetic counselling

(l) outline Darwin's and Wallace's observations and conclusions

(m) describe evolutionary patterns of divergence and adaptive radiation including the Galapagos finches as an example

(n) outline the mechanisms leading to evolutionary changes in allele frequency in populations including: the role of mutation in producing genetic variation; how such variations might enable organisms with particular alleles and particular phenotypes to survive better and reproduce more frequently

(o) describe and explain directional, stabilising and disruptive selection

(p) explain what is meant by the founder effect and genetic drift, and their implications for small isolated populations such as those on islands

(q) discuss what effect increased environmental stress resulting from global climate change (with increased temperatures and more extreme weather conditions) might have on organisms and thus on food chains and niche occupation

(r) suggest how natural events may have led to the disappearance from the fossil record of organisms such as the dinosaurs

(s) compare current and background rates of extinction with those during historical mass extinctions (candidates should be aware that these figures are not agreed by all scientists); the figures referred to should include:

- current (e.g. for mammals currently 45 species per 200 years, overall global estimates mostly between 300 to 30 000 species per year = perhaps 0.01% of species per year)
- background (e.g. among mammals, 1 species every 200 years, globally 1-100 species per year = perhaps 0.00003% of species per year)
- historical mass extinctions (e.g. the Cretaceous: 85% of species over 300,000 years = 0.0003% of species per year)

(t) explain the role of isolation in allopatric speciation (with particular reference to evidence from 'ring species') and sympatric speciation (in relation to behavioural isolation in African cichlids)

(u) explain the causes and effects of bacterial genetic resistance to antibiotics

(v) outline the mechanisms of kin selection and inclusive fitness in relation to altruistic behaviours in social animals including discussion of 'good of the species' misconceptions, group selection and Lack's work on clutch sizes

(w) define the term species with reference to morphological, genetic and biochemical similarities and capability to produce fertile offspring.

(x) discuss the difficulties inherent in definition of species including reference to *Taraxacum* spp. and *Bos/Bison* spp. as well as attempts to define species in relation to molecular clocks and in behavioural and ecological terms

(y) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

4.2 Reproduction

Content

cloning
the significance of sexual reproduction
human sexual reproduction
sexual reproduction in dicotyledonous flowering plants

Learning Outcomes

Candidates should be able to:

(a) explain what cloning is and discuss ethical issues relating to its use in plants, animals and humans

(b) discuss the significance of sexual reproduction in evolutionary terms including the impact of parasite pressure

(c) describe the role of meiosis in maintaining chromosome number and in re-setting telomere length, relating the latter to problems with somatic cell cloning (including premature arthritis in Dolly the sheep)

(d) explain in outline the high cost of sexual reproduction including disruption of adaptive genotypes, finding a mate and sexually transmitted disease relating this to discussion of the possible reasons for its evolution and the fate of asexual populations in changing environments

(e) outline the problems (limited to dessication and lack of liquid medium through which male gametes can swim) associated with sexual reproduction for terrestrial organisms (compared to marine organisms) and explain how these problems have been overcome (in organisms including terrestrial vertebrates)

(f) outline the structure of the human male and female urogenital system

(g) explain the role of hormones (ovarian and from brain [limited to oestrogen, progesterone, FSH and LH]) on ovaries and uterus in the human menstrual cycle

(h) explain what is meant by *in vitro* and *in vivo* fertilisation

(i) explain the roles of the placenta in pregnancy to include

- the transfer of: nutrients (water, glucose, amino acids, simple proteins, lipids, mineral salts, vitamins); oxygen; metabolic waste (carbon dioxide, urea and other nitrogenous waste); hormones; antibodies and antitoxins; potentially harmful bacteria, viruses, toxins and drugs e.g. nicotine and alcohol
- isolation of fetus from maternal blood which both prevents damage due to high maternal blood pressure and also protection from the mother's immune system cells
- production of hormones chorionic gonadotrophin, oestrogen and progesterone and human placental lactogen

(j) describe and discuss the use of synthetic analogues of progesterone and oestrogen in hormonal contraceptives to include the combined pill and progestin-only pill, risk factors and level of protection and changes with age

(k) describe and discuss the use of clomiphene as an oestrogen receptor inhibitor in raising FSH levels during treatment to enhance fertility

(l) state what is meant by the terms self-pollination and cross-pollination and the advantages and disadvantages of each (including reference to inbreeding)

(m) explain the advantages of dioecious species (including no inbreeding) and monoecious species (including all the individuals seed-bearing)

(n) explain the means by which flowering plants transfer the male gametes and ensure that they arrive in the correct place for fertilisation limited to:

- wind pollination including adaptations of anthers, pollen and stigmatic surface
- insect pollination including reference to UV light , guides, nectar, odours, imitation of female insects
- chemotrophic growth of pollen tube to embryo sac

(o) explain in outline the need for double fertilisation in flowering plants, relating this to the functions of endosperm and embryo

(p) outline the origin (in terms of structures from ovary wall inwards), structure and functions of fruits and the seeds that they contain (to include at least one species with an endospermous seed and one with a non-endospermous seed)

(q) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

End of Section 4 synoptic Assessment:

By the end of this section of the course candidates should be able to research and produce an informational outcome such as some kind of presentation or discussion or critical essay or learning aid or poster or flow diagram or chart or other audiovisual means of communicating information. This should be a topic of interest to the candidate from within Section 4, such as: meiosis; aspects of Mendelian genetics; statistics in genetics; variation; aspects of evolutionary mechanisms; impact of environmental change in the past or now; speciation; evolution of social behaviours; aspects of sexual reproduction in mammals or flowering plants; varied classification systems; biodiversity or other evolution-related topics of interest to the individual. It should be distinct from those used in previous sections of the syllabus so that a balance of can-do skills is demonstrated over the duration of the course. It may be communicated by any appropriate means to the group as a synoptic revision exercise.

Practical and research skills associated with Section 4

Learning Outcomes

Candidates should be able to:

(i) investigate meiosis using prepared slides and photomicrographs of plant or animal tissues

(ii) investigate genetics using locally available materials (e.g. people in the class, locally available plants), germinating seedlings (e.g. rapid-cycling *Brassica*), fungi (such as *Sordaria*), prepared materials such as 'genetic corn-cobs' and any other materials that yield suitable numerical information

(iii) investigate continuous and discontinuous variation with any available materials (e.g people, plants with suitable single-gene and polygenic characters, polymorphic snails etc.)

(iv) explain the relationship between structure and function with reference to histological sections and electronmicrographs of mammalian testis, ovary (including follicles and corpus luteum) and placenta as well as flowering plant embryo sacs and developing seeds and fruits

(v) investigate pollination mechanisms and pollen structure as well as growth of the pollen tube in living pollen

(vi) carry out other relevant practical and research activities

5. ORGANISMS IN THE ENVIRONMENT

Some teaching cohorts might prefer to raise a number of shorter scenario questions as a more stimulating approach to this section, for example:

- What defines where a particular organism lives and what it does there?
- How does adaptation relate to success for organisms/species?
- Why are tropical ecosystems so different from polar ones?
- Why can't we just conserve a little bit of an ecosystem successfully?

Preamble

In addition to meeting the aims of the syllabus as a whole, this component is intended to develop:

- insight into the importance of adaptation to organisms, and its relation to their niche occupation
- ability to observe the behaviour of animals and make inferences about its adaptiveness
- ability to investigate species richness and diversity, assess its importance and relate this to its conservation

Recommended Prior Knowledge

Candidates should have a knowledge of

- KS3 or CIE Checkpoint Science or equivalent
- KS4 5a, 5b, 5c, 8a, 8b, 8c or CIE IGCSE Biology, I1, 2, 3, II1, 2, 3, 4, 5, 6, 7, 8, 9, 10, III1, 2, 3, IV1, 2, 3, 4, 5 or equivalent

5.1 Evolutionary and Conservation Ecology

Content

adaptation and the niche
sampling techniques as ecological tools

This could form a key part of a 3-4 day residential field course, or for situations where this is not possible, could be accomplished by a series of fieldwork sessions in the local environment of the Centre, whether this be urban or rural. The same organisms could be studied through outcomes 4.1 (a) to (e) so that candidates are able to form a coherent understanding of the adaptations of the organisms and the way in which these suit the organism to the niche that it occupies.
It is important that at least one of these organisms can be studied in detail in a natural, wild or semi-wild environment (which could include, for example, organisms encountered during a field course, or wild birds or weeds in the school grounds).

It is also important that candidates have the opportunity to study the behaviour of interesting animals doing interesting things, perhaps using audio-visual media or in captivity.

Learning Outcomes

Candidates should be able to:

(a) explain what is meant by the term adaptation by reference to specific physiological and behavioural adaptations of named organisms (which should include organisms that can be directly observed in a natural environment, and additionally might include those that can only be observed in captivity or on screen)

(b) describe physiological and behavioural adaptations of named organisms to the particular challenges posed by their environment, to include animal and plant examples in each of the following environments:

Environment	Animal example	Plant example
desert or sand dune	*Meriones* [gerbil]	*Crassula*
exposed coastal rocky shore	*Patella* [limpet]	*Fucus*
tropical rainforest	*Ateles* [spider monkey]	*Pterocarpus*

(c) explain, with reference to the ways that adaptation or specialisation for a particular habitat may limit the distribution of organisms in general, how the adaptations named in (a) might limit the specific organism's distribution

(d) explain and use the concept of the ecological niche and describe the niches of the organisms named in (a) in terms of the specific environment and habitat to which the organisms are well suited, their place within the ecosystem including what they eat, their activities, and their interactions with other organisms

(e) explain, in outline, how niche size may be restricted by interspecific competition and how founder effects may permit ecological diversification and rapid evolution of species on islands (e.g. ground birds in New Zealand and Mauritius in the absence of mammals)

(f) discuss, with examples including ground birds in New Zealand, the effect of invasive species on isolated communities

(g) list and explain the nature of the problems that are faced by the organisms named in (a) in occupying their niches

(h) assess and describe the physiological, structural and behavioural adaptations of the organisms selected in (a) that enable them to survive successfully in these niches of these ecosystems

(i) explain how an individual's adaptive behavioural strategy can vary within a species, making particular reference to dunnock (including quantitative consideration of reproductive success of different strategies) and red deer (making reference to oestrus and the rut and including the effects of size and condition on sex ratio of offspring)

(j) explain, in outline, why global biodiversity is not uniformly distributed and discuss the possible reasons for the existence of biodiversity hotspots, especially in the tropics

(k) discuss the importance of conservation and explain how information can be used to inform conservation strategies

(l) discuss the consequences of loss of keystone species and the importance of conserving biodiversity in terms of
- the viability and stability of ecosystems
- the interdependence of neighbouring ecosystems (such as mangroves and coral reefs)
- bioprospecting and drug discovery
- the sustainable development of human populations
- amenity value
- moral imperative

(m) use, or interpret data from, quantitative techniques for measuring biodiversity including:
- quadrats to estimate diversity indices (point quadrats, direct counts, percentage cover or relative abundance [ACFORN] scales)
- mark-release-recapture
- remote sensing using satellite images

(n) outline the species-area concept in terms of the positive correlation between the species-richness of an ecosystem and its area

(o) discuss the implications of species-area concept in conservation strategies including the danger of habitat fragmentation (including reference to the SLOSS debate [Single Large Or Several Small reserves] and the importance of corridors)

(p) discuss the reasons why conservation initiatives should acknowledge the needs of developing local communities as part of an integrated management strategy

(q) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

End of Section 5 synoptic Assessment:

By the end of this section of the course candidates should be able to research and produce an informational outcome such as some kind of presentation or discussion or critical essay or learning aid or poster or flow diagram or chart or other audiovisual means of communicating information. This should be a topic of interest to the candidate from within Section 5, such as: field-course report; aspects or examples of adaptation to niches; tropical ecology; aspects of conservation; adaptive

behavioural strategies or other ecology-related topics of interest to the individual. It should be distinct from those used in previous sections of the syllabus so that a balance of can-do skills is demonstrated over the duration of the course. It may be communicated by any appropriate means to the group as a synoptic revision exercise.

Practical and research skills associated with Section 5

Learning Outcomes
Candidates should be able to:

(i) undertake a detailed investigation of the relationship between adaptation, the distribution of organisms and their niches for wild, semi-wild or captive organisms, observed directly or on screen
(ii) investigate quantitatively the species-area concept
(iii) carry out other relevant practical and research activities

6. BIOTECHNOLOGY

Some teaching cohorts might prefer to raise a number of shorter scenario questions as a more stimulating approach to this section, for example:

- What is genetic engineering and is it a good thing or a bad thing?
- How is knowledge and understanding of Biology applied to gene technology and molecular phylogenetics?
- Selective breeding... Is it genetic engineering or not?
- How do I transfer a gene from one species to another, and how can I tell if I've done it successfully?

Preamble
In addition to meeting the aims of the syllabus as a whole, this component is intended to develop:

- understanding of the ways in which molecular genetics can be applied to industrial processes
- awareness of the medical applications of genetic engineering
- knowledge of the processes of genetic engineering and its potential and actual costs and benefits

Recommended Prior Knowledge
Candidates should have a knowledge of

- KS3 or CIE Checkpoint Science or equivalent
- KS4 5a, 5b, 5c, 5d, 5e, 6a, 6b, 6c, 6d, 8a or CIE IGCSE Biology, I1, 2, 3, II1, 2, 4, 5, 6, 8, III1, 2, 3 or equivalent

6.1 Gene Technology

Content

principles
isolating genes
cloning DNA
vectors and insertion into host cells
identifying and cloning transformed cells
genetic profiling
ethics

Learning Outcomes

Candidates should be able to:

(a) state that genetic engineering is only possible because all organisms share the same genetic code system

(b) discuss why traditional selective breeding is often not considered to be genetic engineering and the use of recombinant DNA technology to transfer single genes usually is

(c) discuss the potential and actual advantages and disadvantages of transferring single genes by genetic engineering compared to selective breeding

(d) explain why promoters and other control sequences may have to be transferred as well as the desired gene

(e) discuss the use of promoter regions in the host genome (including their use as a means of producing desirable proteins in milk)

(f) explain strategies that are available to isolate the desired gene from the genome of the gene-donor including:

- use of mRNA and reverse transcriptase (as was done originally with human insulin)
- use of restriction endonucleases to fragment the genome, electrophoresis and use of complementary gene probes to identify relevant fragments
- from primary structure of desired protein

(g) outline the principles of PCR as used to clone and amplify DNA and discuss the source and importance of Taq polymerase

(h) explain strategies that are available to insert DNA into host cells including:

- inserting the DNA into a plasmid vector using restriction enzymes and DNA ligase and then inserting the plasmid vector into a host cell
- use of *Agrobacterium tumefaciens* in inserting DNA into dicotyledonous plant cells
- use of microprojectiles in inserting DNA into monocotyledonous plant cells (e.g. in creating golden rice and golden rice 2)

(i) discuss the advantages and disadvantages of means that have been used to identify transformed cells including antibiotic resistance genes and genes that give fluorescence under UV light

(j) explain the limitations, both potential and actual, of gene therapy as a treatment for genetic disorders (including CF and SCID)

(k) outline the processes used in genetic profiling (DNA fingerprinting) including the use of restriction endonucleases, amplification, electrophoresis and visualisation (e.g. by fluorescently tagged primers)
(l) discuss the ethical implication of the applications of genetic engineering (this should include agricultural, industrial and medical applications)
(m) outline the use of molecular phylogenetics (limited to the use of molecular clocks, identification of homologous DNA sequences, quantifying DNA sequence variations, constructing and evaluating phylogenetic trees representing evolutionary relationships)
(n) refer to the content in this section, when appropriate, in broad-ranging biological evaluation, comparison, discussion and argumentation

End of Section 6 synoptic Assessment:

By the end of this section of the course candidates should be able to research and produce an informational outcome such as some kind of presentation or discussion or critical essay or learning aid or poster or flow diagram or chart or other audiovisual means of communicating information. This should be a topic of interest to the candidate from within Section 6, such as: applications of microbes or enzymes; immobilisation; glucose monitoring; antibiotics; aspects of ethics in biotechnology; DNA profiling; aspects of the biology of genetic disorders; genetics in the health services; monoclonal antibodies; aspects of genetic engineering; promoters; PCR; vectors and insertion of DNA into host cells; identification of successfully transformed cells or other biotechnology-related topics of interest to the individual. It should be distinct from those used in previous sections of the syllabus so that a balance of can-do skills is demonstrated over the duration of the course. It may be communicated by any appropriate means to the group as a synoptic revision exercise.

Practical and research skills associated with Section 6

Learning Outcomes
Candidates should be able to:

(i) investigate aspects of genetic profiling including practical investigation of electrophoresis of DNA fragments
(ii) investigate transformation of bacteria
(iii) use a variety of protocols to investigate aspects of biotechnology such as some of those in the NCBE Practical Biotechnology guide
(iv) carry out other relevant practical and research activities

Appendix 1: 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:

- 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

Practical Assessment will be through Component 4, a Practical examination paper.

COMPONENT 4

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
- making microscopic observations, drawing and magnification calculations from unfamiliar structures of specimens
- following instructions to use unfamiliar biochemical procedures

Component 4 will consist of two sections designed to be completed either Section A or B first. Section A will be a laboratory-based practical section focusing on skills of experimentation and Section B will not require a laboratory, focusing on higher-order practical skills. This will enable Centres to divide candidates into two groups and run two sessions of laboratory work. One group may start with Section A in the laboratory and the other group with Section B in an adjacent examination room. Half-way through the allotted time, the two groups may be reversed, ensuring that security is carefully maintained during the changeover.

Section A focuses on the following experimental skills:

- manipulation of apparatus
- presentation of data

Section A:

- 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 Biology, and may include material from unfamiliar contexts (see above)

Apparatus requirements for Section A

The apparatus requirements for Section A 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.

Section B will focus on the following higher-order experimental skills:

- planning
- analysis and evaluation

Section B of component 4 will **not** require laboratory facilities.

It should be stressed that candidates cannot be adequately prepared for Section B 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.

Section B 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 Section B 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 Pre-U 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 Component 4

Component 4 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***	
Section A Manipulation, measurement and observation	24 marks	Successful collection of data and observations	14 marks
		Decisions about measurements or observations	10 marks
Section A Presentation of data and observations	10 marks	Recording data and observations	4 marks
		Display of calculation and reasoning	3 marks
		Data layout	3 marks
Section B Planning	16 marks	Defining the problem	6 marks
		Methods	10 marks
Section B Presentation of data and observations	3 marks	Data layout	3 marks
		Interpretation of data or observations and identifying sources of error	10 marks
Section B Analysis, conclusions and evaluation	17 marks	Suggesting improvements and Evaluation	4 marks
		Conclusion	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 it 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 a 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.

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 in the future tense and impersonal voice 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

Interpretation of data or observations and identifying sources of error

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
- 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

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, 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.

Descriptions of patterns and trends 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 ± 1mm, or temperature increase = 14 °C ± 4 °C. Candidates should be able to suggest which of the sources of error described are likely to be systematic errors such as those 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.

Suggesting improvements and Evaluation
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
- 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

Candidates' suggestions should be realistic, so that in principle they are achievable in practice. The suggestions may relate either to the apparatus described in the question, or to the experimental procedure or to the nature of the observations or the means used to make them. Candidates may include improvements that they would have made while carrying out the experiment had they done it themselves, 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.

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

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

Drawing conclusions
Candidates should be able to:

- draw conclusions from an investigation or from interpretations of observations, data and calculated values, providing a detailed description of the key features of the observations, 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 understanding that they have gained from their studies of the Pre-U 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 using the past tense and impersonal voice, 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. 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. 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.

LABORATORY EQUIPMENT

The following is a list of basic materials and apparatus which would be expected for a Centre providing this qualification. 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
H = harmful or irritating substance
T = toxic substance
F = highly flammable substance
O = oxidising substance
N = environmentally hazardous 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 (one each or one between two)
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
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 and other specimens to show:
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*)
prokaryote and eukaryote fossils as real specimens, simulations, and various types of image

Microscale

Centres are encouraged to incorporate some microscale chemistry into their Biology Pre-U laboratory work. Manipulative skills on this small scale are becoming increasingly relevant in modern research. The kit is cheap compared to conventional apparatus, and working with such small quantities of chemicals is money-saving. Experiments take much less time and are much less likely to require the sharing of apparatus between candidates; with all the required materials on a personal palette, microscale work generates quiet independent work. Many health and safety barriers are removed by working on such a small scale – risks are minimised when tiny quantities are involved; the experiments can even be done in classrooms rather than laboratories. Quantitative work that involves mass measurement is less advantageously carried out as microscale though, due to the percentage mass errors. Microscale will not be required for practical exams.

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 is an advisory service providing support in science and technology, primarily for UK schools. Independent and international schools and post-16 colleges can apply for associate membership which includes access to the CLEAPSS publications listed below, 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

Appendix 2: Textbooks and IT Resources

A textbook specifically for the course is in preparation. However, at present the best textbook at this level is:

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

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 candidates 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 candidates although these are usually organised in a different way from the syllabus.

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

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

Biozone *(2004) Advanced Biology AS, Advanced Biology A2* – Candidate 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

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

Campbell, N A, Reece, J B *(2007) Biology with MasteringBiology*™ (Benjamin Cummings; 8th Edition) ISBN 0321543254

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

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

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

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

Freeman, S *(2008) Biological Science* (Pearson Education; 3rd Edition) ISBN 0321546210

Gould, J L, Keeton, W T, Gould, C G *(1997) Biological Science* (W. W. Norton & Company; 6th Edition) ISBN 0393969207

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

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

Jones, M, Fosbery, R, Taylor, D, Gregory, J (2003) CIE Biology AS and A Level (CUP, www.cambridge.org) ISBN 052153674X

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

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

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

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

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

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

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

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

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

*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

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

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

Taylor, M R, Campbell, N A *(2005) Study Guide for Biology* (Pearson Publications Company; 7th Student Edition) ISBN 0805371559

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

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, J G, Brown Carter, M E *(2005) Investigating Biology Lab Manual* (Benjamin Cummings; 5th Edition) ISBN 0805371796

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

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)

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

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 microsope. 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 Pre-U syllabus.
(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 candidates, based on real experimental data. It includes superb candidate 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

Appendix 3: Mathematical Requirements

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 2 mm square graph paper
- for linear graphs, calculate the rate of change
- recognise when it is appropriate to join the points with straight ruled 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).
- 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

Principal candidates should know how to apply a *t*-test, chi-squared test and standard error. *t*-tests are of value in much of Biology 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 $s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$

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

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

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 Component 4.

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

Appendix 4: Grade Descriptors

The following grade descriptors indicate the level of attainment characteristic of the given grade. They give a general indication of the required standard at each specified grade. The descriptors should be interpreted in relation to the content outlined in the syllabus; they are not designed to define that content.

The grade awarded will depend in practice upon the extent to which the candidate has met the assessment objectives overall. Shortcomings in some aspects of the examination may be balanced by better performance in others.

Distinction (D2)

Candidates recall and use knowledge of Biology from the whole syllabus with few omissions and show good understanding of many of the most demanding principles and concepts in the syllabus. They select appropriate information from which to construct arguments or techniques with which to solve problems. In the solution of problems, candidates are usually able to bring together fundamental principles from different content areas of the syllabus and demonstrate a clear understanding of the relationships between these.

Candidates apply knowledge and biological principles contained within the syllabus in both familiar and unfamiliar contexts. In questions requiring numerical calculations, candidates demonstrate good understanding of the underlying relationships between quantities involved and carry out all elements of extended calculations correctly in situations where little or no guidance is given. They are often successful on questions which require a combination of applying demanding concepts to unfamiliar contexts, extended problem-solving and synthesis of ideas from different areas of Biology.

In experimental activities, candidates identify a problem, formulate a clear and effective plan using knowledge and understanding of Biology, and use a range of relevant techniques with care and skill. They are organised and methodical in the way they carry out their work and present their results. They make and record measurements which are sufficient and with a precision which is appropriate to the task. They interpret and explain their results with sound use of biological principles and evaluate critically the reliability of their methods.

Merit (M2)

Candidates recall and use knowledge of Biology from most parts of the syllabus with some omissions and show good understanding of many of the principles and concepts within it. They select appropriate information from which to solve problems, including some problems in unfamiliar contexts. Candidates show some signs of an ability to bring together fundamental principles from different content areas of the syllabus, but do not do so consistently. They usually make good use of the concepts and terminology of Biology in communicating their answers.

Candidates apply knowledge and principles of Biology contained within the syllabus in familiar and some unfamiliar contexts. In questions requiring numerical calculations, candidates demonstrate some understanding of the underlying relationships between quantities involved and are usually aware of the magnitudes of common quantities. Candidates are usually successful in calculations where some structure is provided and can carry out some elements of extended calculations correctly.

In experimental activities, candidates are usually able to identify a problem and to formulate a plan, many aspects of which are realistic and practicable. They use a range of relevant techniques with care and skill. They make and record measurements, usually with a precision which is appropriate to the task. They interpret and explain their results using biological principles and make some critical evaluation of their methods.

Pass (P2)

Candidates recall and use knowledge of Biology from many parts of the syllabus and demonstrate some understanding of a number of the main principles and concepts within it. Their level of knowledge and understanding may vary significantly across major areas of the syllabus. They select discrete items of knowledge and make some use of information that is presented in familiar ways to solve problems. They make some use of the concepts and terminology of Biology in communicating their answers.

Candidates apply knowledge and principles of Biology contained within the syllabus to material presented in a familiar or closely related context. They show some understanding of the magnitudes of common quantities when carrying out numerical work. Candidates carry out straightforward calculations in most areas of Biology correctly when these calculations are of a familiar kind and when structure is provided, usually using correct units.

In experimental activities, candidates are able to plan some aspects of the solution to a practical problem. They make and record appropriate measurements and show some awareness of the need for precision. They usually offer an interpretation of their experimental results making some use of fundamental principles of Biology.

Appendix 5: Additional information

Guided Learning Hours

It is intended that each Principal Subject should be delivered through 380 hours of guided learning. This is a notional measure of the substance of the qualification. It includes an estimate of the time that might be allocated to direct teaching or instruction, together with other structured learning time such as directed assignments or supported individual study and practice. It excludes learner-initiated private study.

Certification Title

This qualification is shown on a certificate as:

- Cambridge International Level 3 Pre-U Certificate in **Biology (Principal)**

The qualification is accredited at Level 3 of the UK National Qualifications Framework and provides a solid grounding for candidates to pursue a variety of progression pathways.

Entries

For Entry information please refer to the *Pre-U E3 Booklet*.

Grading and Reporting

The Cambridge International Level 3 Pre-U Certificates in the Principal Subjects are qualifications in their own right. They are acceptable as an alternative to A Level (or other Level 3 qualifications) for entry into Higher Education or employment. Each individual Principal Subject is graded separately on a scale of nine grades: Distinction 1, Distinction 2, Distinction 3, Merit 1, Merit 2, Merit 3, Pass 1, Pass 2, Pass 3.

Subjects can also be combined with two core components to meet the requirements for eligibility for the Cambridge International Level 3 Pre-U Diploma. More details about the Diploma requirements and the core components can be found in a separate Diploma syllabus. The results of the individual Principal Subjects are reported on a separate certificate to the Diploma result.

Classification Code for UK Centres

In the UK, every syllabus is assigned to a national classification code that indicates the subject area to which it belongs. UK Centres should be aware that candidates who enter for more than one qualification with the same classification code will have only one grade (the highest) counted for the purpose of the School and College Performance Tables.

The classification code for this syllabus is **1010**.

Language

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

Procedures and Regulations

This syllabus complies with the *CIE Code of Practice* and *The Statutory Regulation of External Qualifications 2004*.

Further information about the administration of Cambridge Pre-U qualifications can be found in the *CIE Handbook for Cambridge Pre-U Centre*s available from CIE Publications or by contacting international@cie.org.uk

Spiritual, Moral, Ethical, Social, Legislative, Economic and Cultural Issues

The syllabus provides a number of areas in which candidates may appreciate the moral, social, ethical, economic and cultural issues surrounding biotechnological industries, biological research and conservation both on a local and on a global scale. It is expected that candidates will gain a deeper appreciation and understanding of the molecular and life science workings of the world around them. There are no legislative issues in this syllabus.

Health and Safety Issues

The following health and safety issues feature in this syllabus:

- safe practice in laboratories
- issues associated with the impact of biotechnological industry and environmental research

Health and safety issues are covered in Appendix 1.

Environmental Education and Sustainable Development

Aspects of environmental education and sustainable development occur in relation to reducing the impact of Biotechnology/Gene Technology and Organisms in the Environment/Evolutionary and Conservation Ecology.

Aspects of environmental education and sustainable development are covered throughout the syllabus.

European and International Dimension

There are opportunities in this syllabus to investigate local, national and international contributions to the subject field and to appreciate the global significance and impact of Biology. For example, the underlying evolutionary paradigm gives global relevance throughout the syllabus, but in particular, section 1: chemicals of life; section 2: genes and protein synthesis, mammalian immunity; section 4: sexual reproduction, biodiversity, adaptation and classification; section 5: evolutionary and conservation ecology; section 6: gene technology.

Avoidance of Bias

CIE has taken great care in the preparation of this syllabus and assessment materials to avoid bias of any kind.

Key Skills

This syllabus provides opportunities for the development of evidence for the Key Skills of: *Communication*, *Application of Number*, *Information Technology*, *Working with Others*, *Improving Own Learning and Performance* and *Problem Solving* at Levels 2 and/or 3. However, the extent to which this evidence fulfils the Key Skills criteria at these levels will be totally dependent on the style of teaching and learning adopted for each section.

The Key Skills awarding bodies and the regulatory authorities have produced a suite of example portfolios that will help to give candidates and practitioners a clear understanding of the requirements for the Key Skills portfolio. These are available on the QCA Key Skills website (www.qca.org.uk/keyskills). Full details of the requirements for certification can be obtained from the awarding bodies that are approved to offer Key Skills. For further information about Key Skills assessment, including the current standards, please see the document *The Key Skills Qualifications Standards and Guidance* published by the Qualifications and Curriculum Authority 2004 (ISBN 1 85838 548 2).

The following table indicates where opportunities may exist for at least some coverage of the various Key Skills criteria at Levels 2 and/or 3 for each section.

Section	Communication	Application of Number	IT	Working with Others	Improving own Learning and Performance	Problem Solving
1	✓		✓	✓	✓	✓
2	✓		✓	✓	✓	✓
3	✓		✓	✓	✓	✓
4	✓	✓	✓	✓	✓	✓
5	✓	✓	✓	✓	✓	✓
6	✓		✓	✓	✓	✓

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.
   Explain how indicates that the candidate should show the way that something works.
   Explain why indicates that the candidate should give the reasons why an event, process or outcome occurs; that the candidate should show what causes the system to do what it does.
   (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. This may include considering the issues, giving information to build an argument, or to permit weighing of both sides of an argument.
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.
    In multiple choice questions, *deduce* is used to mean that candidates should use the information presented in the question plus their own skills, knowledge and understanding from across the Biology syllabus to solve the problem or problems required in order to answer the question.
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) *Sketch* 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. The mark allocation should provide the candidate with a guide to how many reasons to give, or how much detail to give for each reason.

University of Cambridge International Examinations
1 Hills Road, Cambridge, CB1 2EU, United Kingdom
Tel: +44 1223 553554 Fax: +44 1223 553558
Email: international@cie.org.uk Website: www.cie.org.uk