CAMBRIDGE
International Examinations

Cambridge
Pre-U

SYLLABUS

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

9790

For examination in 2019, 2020 and 2021

This syllabus is regulated for use in England, Wales and Northern Ireland as a Cambridge International Level 3 Pre-U Certificate. QN: 500/3807/2

Cambridge Advanced

Version 1

Changes to the syllabus for 2019, 2020 and 2021

The syllabus has been updated. The latest syllabus is version 1, published September 2016.

Syllabus changes

The following learning outcomes and content have been updated:

- Page 20, 1.4(f) candidates should be able to describe an example of inherited metabolic diseases.
- Page 20, 1.5 content: anaerobic respiration has been clarified.
- Page 20, 1.5(e) requirements have been clarified.
- Page 21, 1.6(k) ionising radiation has been clarified.
- Page 22, 1.7(h) reference to match tables has been deleted.
- Page 25, 2.4(e) has been updated.
- Page 29, 3.5(j) 'discuss and evaluate' has been changed to 'describe and explain'.
- Page 33, 5.1(e) has been updated.

In addition, the Apparatus and materials list, including the list of chemicals and reagents, has been updated.

TQT

We have added guidance on Total Qualification Time value (TQT). TQT includes both guided learning hours and independent learning activities. The number of hours required to gain the qualification may vary according to local curricular practice and the learners' prior experience of the subject.

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

You are strongly advised to read the whole syllabus before planning your teaching programme.

Contents

Introduction

Why choose Cambridge Pre-U?

Cambridge Pre-U is designed to equip learners with the skills required to make a success of their studies at university. Schools can choose from a wide range of subjects.

Cambridge Pre-U is built on a core set of educational aims to prepare learners for university admission, and also for success in higher education and beyond:

- to support independent and self-directed learning
- to encourage learners to think laterally, critically and creatively, and to acquire good problem-solving skills
- to promote comprehensive understanding of the subject through depth and rigour.

Cambridge Pre-U Principal Subjects are linear. A candidate must take all the components together at the end of the course in one examination series. Cambridge Pre-U Principal Subjects are assessed at the end of a two-year programme of study.

The Cambridge Pre-U nine-point grade set recognises the full range of learner ability.

Why choose Cambridge Pre-U Biology?

- Cambridge Pre-U Biology provides a balanced and solid foundation in the subject through the major themes of cell biology, evolution and the fundamentals of life, whole organism biology and environmental biology. Breadth and depth are carefully balanced to allow opportunities for the exploration of topics in greater detail while retaining a broad view of biology in a manageable learning framework.
- Cambridge Pre-U Biology incorporates cutting-edge science in fields such as molecular genetics, biotechnology, and immunology, reflecting the subject's exciting and rapid rate of development in the last 20 years.
- The linear assessment structure, in which learners are tested at the end of the two-year course, allows learners time to develop their knowledge, understanding and skills, and make links between different topics. It allows teachers great flexibility when delivering the course; different learning styles can be accommodated easily and teachers can adopt content or context approaches to the subject.
- Cambridge Pre-U Biology assessment, which includes synoptic analysis, argumentation, data analysis and planning, is varied in approach to encourage the development of a wide range of skills and a deeper understanding of the subject.
- Assessment includes a practical examination that encourages the teaching and learning of practical skills as an integrated part of the course and is designed to reward a wide range of laboratory and higher-order practical skills.

Prior learning

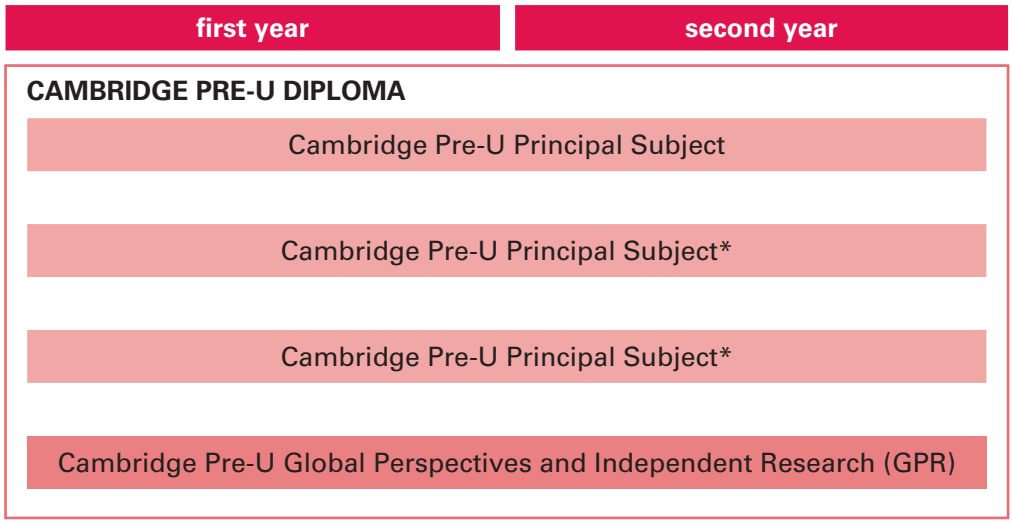
Cambridge Pre-U builds on the knowledge, understanding and skills gained by learners achieving a good pass in Level 1/Level 2 qualifications in Biology or related subjects.

Progression

Cambridge Pre-U is considered to be an excellent preparation for university and employment. It helps to develop the in-depth subject knowledge and understanding which are so important to universities and employers. Cambridge Pre-U Biology concentrates on the development of skills such as analysis and synthesis associated with studying biological sciences at a higher level and encourages independent study and research and collaborative working, which are useful in all university courses. The course will equip learners 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 and applied sciences), while providing thought-provoking material to appeal to those who do not wish to pursue a scientific career.

Cambridge Pre-U Diploma

If learners choose, they can combine Cambridge Pre-U qualifications to achieve the Cambridge Pre-U Diploma; this comprises three Cambridge Pre-U Principal Subjects* together with Global Perspectives and Independent Research (GPR). The Cambridge Pre-U Diploma, therefore, provides the opportunity for interdisciplinary study informed by an international perspective and includes an independent research project.



* Up to two A Levels, Scottish Advanced Highers or IB Diploma programme courses at higher level can be substituted for Principal Subjects.

Learn more about the Cambridge Pre-U Diploma at **www.cie.org.uk/cambridgepreu**

Support

Cambridge provides a wide range of support for Pre-U syllabuses, which includes recommended resource lists, Teacher Guides and Example Candidate Response booklets. Teachers can access these support materials at Teacher Support **http://teachers.cie.org.uk**

Syllabus aims

The aims of the syllabus, listed below, are the same for all candidates and are to:

- stimulate and motivate learners to take responsibility for their learning by pursuing topics beyond the syllabus, progressing towards a broad and deep knowledge and understanding of biology
- promote independent learning and analysis
- instil in learners safe laboratory practices and equip them with the necessary laboratory skills to pursue the subject further
- develop an understanding of the development of biology through the scientific method in which theories are based on observation, experimental results and deduction
- promote an awareness of the use and development of scientific models
- stimulate a caring interest in the environment, encompassing the environmental impact of human activities, including bioscience and its applications
- 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
- develop an understanding of the links between biology, chemistry, physics and other areas
- develop attitudes relevant to science such as initiative, inventiveness, objectivity, integrity, the skills of enquiry, and concern for accuracy and precision
- provide the tools for learners to develop an informed interest in scientific issues, become confident citizens in a technological world, and participate in public debate on socio-scientific issues.

Scheme of assessment

For Cambridge Pre-U Biology, candidates take all four components.

Component	Weighting
Paper 1 Structured **2 hours 30 minutes** In Section A (20 marks), candidates answer 20 objective questions (multiple choice, single-word answer or equivalent). Section B (80 marks) consists of a number of structured short-answer questions. 100 marks Externally assessed	40%
Paper 2 Data Analysis and Planning **1 hour 15 minutes** Section A Data Analysis (35 marks) consists of a variable number of questions based on source material, which test the higher-order skills of interpretation, analysis, making conclusions, and evaluation. Section B Planning (25 marks) requires candidates to write a highly structured plan drawing particularly on practical skills gained during their course. 60 marks Externally assessed	22.5%
Paper 3 Case Study and Synoptic Essay **1 hour 45 minutes** Section A Case Study (30 marks) is based on source material, typically in the form of articles (e.g. adapted from journals), followed by structured questions. In Section B Synoptic Essay (30 marks), candidates are presented with a choice of one from three unstructured questions, requiring responses in the form of a discursive essay. This includes assessment of the quality of written communication. 60 marks Externally assessed	22.5%
Paper 4 Practical **2 hours 30 minutes** This focuses on the assessment of Section 6 of the syllabus content together with the practical learning outcomes from Sections 1 to 5. Section A (45 marks) consists of one or two practical-based questions. Section B (35 marks) assesses the use of a microscope and its related skills and may involve analysis and interpretation of secondary data. 80 marks Externally assessed	15%

Since this is a linear assessment, each component will be based on the whole of the syllabus content.

Availability

This syllabus is examined in the June examination series.

This syllabus is available to private candidates with the exception of Component 4, which may be carried forward from a previous series.

Combining this with other syllabuses

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

Assessment objectives

AO1	**Knowledge with understanding** Candidates will be expected to demonstrate knowledge and understanding in relation to: • scientific phenomena, facts, laws, definitions, quantities, principles, concepts and theories, and the relationships and models used to explain them • scientific vocabulary, terminology and conventions (including symbols, quantities and units) • scientific instruments, apparatus and methods, and their uses • scientific developments and the methodology used to develop knowledge. The syllabus content defines the actual knowledge that candidates may be required to recall and explain.
AO2	**Application of knowledge and problem solving** Candidates will be expected to: • select, organise, interpret and present scientific information • translate information from one form to another (including manipulating numerical and other data) • analyse scientific information by identifying and explaining patterns and trends, drawing inferences and conclusions, and constructing arguments • evaluate scientific information in terms of validity, accuracy and precision • apply and synthesise scientific skills, knowledge and understanding to solve problems and explain phenomena. This assessment objective relates primarily to unfamiliar data, phenomena or situations which, by definition, cannot be listed in the syllabus content.
AO3	**Experimental and investigative skills** Candidates will be expected to: • plan scientific investigations (including constructing and testing hypotheses and predictions) • use scientific apparatus, methods and techniques skilfully and safely • make, record and communicate observations, measurements and methods methodically with appropriate clarity, precision and accuracy • manipulate, present and analyse raw data from scientific experiments and investigations • report findings and conclusions, supported by evidence • evaluate experimental methods, techniques, raw data and conclusions, identify limitations and suggest improvements.

Relationship between scheme of assessment and assessment objectives

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

Assessment objectives as a percentage of the qualification

Assessment objective	Weighting in Pre-U %
AO1 Knowledge with understanding	40
AO2 Application of knowledge and problem solving	40
AO3 Experimental and investigative skills	20

Assessment objectives as a percentage of each component

Assessment objective	Weighting in components %			
	Paper 1	Paper 2	Paper 3	Paper 4
AO1	55	22	58	0
AO2	45	43	42	20
AO3	0	35	0	80

Grading and reporting

Cambridge International Level 3 Pre-U Certificates (Principal Subjects and Global Perspectives Short Course) are qualifications in their own right. Cambridge Pre-U reports achievement on a scale of nine grades: Distinction 1, Distinction 2, Distinction 3, Merit 1, Merit 2, Merit 3, Pass 1, Pass 2 and Pass 3.

Cambridge Pre-U band	Cambridge Pre-U grade
Distinction	1
	2
	3
Merit	1
	2
	3
Pass	1
	2
	3

Grade descriptions

Grade descriptions are provided to give an indication of the standards of achievement likely to have been shown by candidates awarded particular grades. Weakness in one aspect of the examination may be balanced by a better performance in some other aspect.

The following grade descriptions indicate the level of attainment characteristic of the middle of the given grade band.

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 show a broad knowledge and understanding of biology consistent with extensive reading around the subject and research.

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 practical 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 that is appropriate to the task. They interpret and explain their results with sound use of biological principles and critically evaluate the validity 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 show some evidence of knowledge and understanding of biology consistent with some reading and research.

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 practical 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 show little evidence of knowledge and understanding of biology beyond the defined syllabus content.

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 practical 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.

Description of components

Component 1: Structured

Written paper, 100 marks, 2 hours 30 minutes

This paper consists of two sections:

- Section A (20 marks). This consists of 20 objective questions. These may be multiple-choice questions where candidates choose the correct response from four or more alternatives, or structured questions requiring a single-word answer or equivalent.
- Section B (80 marks). This consists of a number of structured, short-answer questions.

Component 2: Data Analysis and Planning

Written paper, 60 marks,1 hour 15 minutes

This paper consists of two sections:

- Section A: Data Analysis (35 marks). This section includes tasks to assess the higher-order skills of interpreting, analysing, making conclusions and evaluating. The section has a variable number of questions, which require candidates to solve problems. Questions may ask candidates to interpret data given in a table, chart or graph. Candidates may also be expected to plot graphs and charts.
- Section B: Planning Task (25 marks). The Planning Task involves candidates writing a highly structured plan drawing on the practical skills they have developed during their course.

Component 3: Case Study and Synoptic Essay

Written paper, 60 marks,1 hour 45 minutes

This paper consists of two sections:

- Section A: Case Study (30 marks). This consists of several structured questions relating to a passage (or passages) that may be taken or adapted from a source or sources, such as scientific journals and books. These may not necessarily relate directly to the content of the syllabus. Questions may ask candidates to explain the meaning of terms used, analyse information and data, perform calculations or draw conclusions from what they have read. Candidates are advised to spend no more than 50 minutes on this section.
- Section B: Synoptic Essay (30 marks). This section, which may include textual or other stimulus material, consists of a choice of one from a selection of three unstructured questions requiring responses in the form of discursive essays. Quality of written communication is assessed. Candidates should use clear English and are expected to produce well-structured arguments. Questions in this section may be set on any area of the syllabus, and candidates will often need to use material from different areas of the syllabus within a single answer. Marks will also be available for evidence of relevant reading around the subject. 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. Candidates are advised to spend no more than 50 minutes on this section.

Component 4: Practical

Laboratory-based practical examination, 80 marks, 2 hours 30 minutes

This paper consists of two sections:

- Section A (45 marks). This consists of one or two practical-based questions.
- Section B (35 marks). This consists of one or more questions involving the use of a microscope and its related skills. In addition, candidates may be provided with secondary data to analyse and interpret.

The skills that are to be developed by the candidates during the course, and thus the skills that will be tested during the examination, are set out in Section 6 of the syllabus content, and within the practical learning outcomes listed within each section of the syllabus. Candidates will need to have considerable experience of practical work, including planning and carrying out investigations, in order to succeed in the tasks set.

The examination will not be of the open-book type and there will not be any pre-release material for candidates. Candidates will be expected to make decisions about how to carry out the practical work, including the number of measurements to take, preparation of solutions at a range of concentrations, and setting up of controls. They will not be presented with a complete set of instructions to follow.

There will be Confidential Instructions for Centres, which will facilitate the setting up of the examination in an appropriate way. The practical set up will not be onerous for Centres that have been running appropriate Pre-U Biology practical work during the course.

Centres can divide their candidates into two sessions to facilitate laboratory management if they wish. 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.

Contexts for questions on written papers

Questions, where possible, will be set in novel contexts featuring various applications of biology, some of which will be unfamiliar. Medicine, veterinary science, pharmacology, crop and livestock production, conservation, forensics, genomics and proteomics are some of the areas that may provide contexts for questions. Some questions may be set in the context of recent research. Historical and ethical scenarios will also be used. Familiar practicals from within the syllabus as well as unfamiliar practicals will be used as contexts for questions that candidates are expected to answer based on the practical skills that they have developed.

Nomenclature and units

Candidates are expected to be familiar with the nomenclature used in the syllabus. The proposals in *Signs, Symbols and Systematics* (The Association for Science Education Companion to 16–19 Science, 2000) will generally be adopted.

In practical work, candidates will be expected to use SI units or, where appropriate, units approved by the BIPM for use with the SI (e.g. minute). A list of SI units and units approved for use with the SI may be found in the SI brochure at **http://www.bipm.org**. The use of imperial/customary units such as the inch and degree Fahrenheit is not acceptable and should be discouraged.

In all examinations, where data are supplied for use in questions, candidates will be expected to use units that are consistent with the units supplied, and should not attempt conversion to other systems of units unless this is a requirement of the question.

Syllabus content

The syllabus is divided into six sections, as follows:

1 The cell

1.1 Eukaryotic cell structure
1.2 Prokaryotic cells
1.3 Cell replication
1.4 Enzymes
1.5 Respiration
1.6 Genes and protein synthesis
1.7 Applications of cell biology

2 The origin and evolution of life

2.1 The origins of life
2.2 The chemicals of life
2.3 The evolution of life
2.4 Classification

3 Animal physiology

3.1 Transport systems
3.2 Nutrition
3.3 Nerves, muscles and behaviour
3.4 Homeostasis and cell signalling
3.5 The immune system
3.6 Reproduction

4 The life of plants

4.1 Transport in plants
4.2 Photosynthesis
4.3 Reproduction
4.4 Control of plant processes

5 Environmental studies

5.1 Adaptation
5.2 Measuring and conserving biodiversity

6 Practical biology

6.1 Planning and decision making
6.2 Manipulation, measurement and observation
6.3 Presentation of data and observations
6.4 Analysis of data and conclusions
6.5 Evaluation of procedures and data

Cambridge Pre-U Biology places considerable emphasis on the understanding and use of scientific ideas and principles in a variety of situations, including those which are new to learners. As described in the Aims, it is expected that programmes of study based on this syllabus will feature a variety of teacher-centred and student-centred learning experiences designed to enhance the development of skills and comprehension. They will also prepare learners 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 learners.

Teachers should take note of the greater than 50 per cent weighting for skills (including handling information, solving problems, and practical, experimental and investigative skills) compared to less than 50 per cent 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 learners prepared for the assessment.

It is expected that every learner, regardless of ability, will cover the content as described and will thus be able to approach the examination with the confidence that they will find it accessible at a level that reflects their ability and current developmental status as a biologist. Higher achievers will have read around, investigated, discussed and thought about a wide range of additional material.

In each section of the syllabus it is anticipated that learners will use the content for broad-ranging discussion and argumentation. It is expected that learners will carry out their own research, and will bring their own interests to bear, on particular topics to the benefit of the whole group. This will prepare all the learners for the more discursive aspects of the course and will prepare them well for study at university.

Similarly, learners may wish to extend their study of the practical work by carrying out other research activities that may or may not involve further practical work.

In the context of the syllabus content learning outcomes, 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 covered the specified examples or have studied the topic to the specified level of detail as applicable.
Including … and e.g. …	Sufficient examples or details are given to form a coherent understanding without any further exemplification or detail. However, for some individual learners or cohorts, there may usefully be the opportunity to pursue the topic to a greater depth. 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 the centrioles and nuclear membrane.
Command words such as state, outline, describe, explain, suggest, 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.
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. Question setters will assume that no candidates have studied the material specifically excluded.

1 The cell

This section looks at life in terms of the cell. Knowledge of eukaryotic and prokaryotic cellular structure and the processes which take place in all living cells is fundamental to explaining how life 'works'. Cell biology has medical and commercial applications and these are also considered in this section.

1.1 Eukaryotic cell structure

Content

- microscopy
- cell membranes
- organelles: structure and function

Candidates should be able to:

(a) discuss the relative advantages of light and electron microscopes

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

(c) discuss the importance of cell membranes in delimiting and compartmentalising cells, in selecting and moving substances across membranes and in providing surfaces for reactions

(d) describe and explain the fluid mosaic model

(e) discuss the roles of membrane proteins including transporters (channels and carriers [including CFTR]), receptors and antigens

(f) describe the factors affecting the permeability and fluidity of membranes

(g) explain how and why different substances move across membranes including simple and facilitated diffusion, osmosis, active transport, endocytosis (phagocytosis and pinocytosis) and exocytosis (secretory pathway)

(h) recognise the following cell organelles and describe their functions:

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

Practical

Candidates should be able to:

(i) use a light microscope, stage micrometer scale and eyepiece graticule

(ii) measure the size of objects viewed with a light microscope and calculate the magnification of an image or drawing

(iii) produce drawings of an organism, a section through a small organism and a part of an organism as seen under the light microscope

(iv) produce correctly labelled and annotated drawings of cells from microscopic examination and from electron micrographs

(v) recognise organelles in a variety of cells from across the four eukaryotic kingdoms

(vi) investigate the movement of materials through cell membranes, for example by diffusion, osmosis and active transport

(vii) estimate the water potential of a plant tissue by investigating the change in length or mass of suitable plant tissue

(viii) estimate the solute potential of plant cells using percentage plasmolysis of suitable plant epidermal cells

(ix) investigate the effect of temperature and different solvents on the permeability of membranes

(x) investigate endocytosis and intracellular digestion in a protoctist, such as *Paramecium* or *Vorticella*, or using yeast stained with neutral red.

1.2 Prokaryotic cells

Content

- structure of prokaryotic cells
- pathogenic bacteria
- antibiotics
- reproduction

Candidates should be able to:

(a) outline key structural features of prokaryotic cells including: unicellular, 1–5 μm diameter, peptidoglycan cell walls, lack of membrane-bound organelles, naked circular DNA, 70S ribosomes

(b) outline the structure of the cell walls of Gram-positive and Gram-negative bacteria and the significance of the structure for the use of antibiotics

(c) explain the mode of transmission and infection of *Agrobacterium tumefaciens* as an example of a bacterial pathogen

(d) explain the mode of action of penicillin on bacteria (as an example of an antibiotic) and explain why penicillin does not affect viruses

(e) outline the mechanism of asexual reproduction by binary fission in a typical prokaryote.

Practical

(i) investigate Gram staining of bacterial cell walls

(ii) investigate the effect of penicillin or other antibiotics on bacterial growth (e.g. by use of antibiotic susceptibility discs).

1.3 Cell replication

Content

- DNA replication
- mitosis
- meiosis

Candidates should be able to:

(a) outline the semi-conservative replication of DNA

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

(c) describe and explain mitosis, with the aid of diagrams, in terms of chromosome, nuclear envelope and (where present) 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

(d) outline the roles, in the control of the cell cycle, of checkpoints, extracellular growth factors and the cell-signalling pathway that activates protein kinases

(e) describe how telomere shortening determines the number of divisions of a cell by mitosis and the role of telomerase reverse transcriptase to reverse the telomere 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 meiosis, with the aid of diagrams, in terms of chromosome, nuclear envelope and (where present) centriole behaviour with emphasis on the features of chromosome behaviour that contribute to reductional division

(g) explain how independent assortment and crossing over can contribute to genetic variation (details of stages within prophase I are not required).

Practical

Candidates should be able to:

(i) sequence images of eukaryotic cells undergoing mitosis

(ii) prepare and view slides of root tip squashes or other material showing mitosis

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

[see also Section 3.6 Practical (i)]

1.4 Enzymes

Content

- structure and function of enzymes
- enzyme kinetics
- commercial uses of enzymes

Candidates should be able to:

(a) discuss why enzymes are essential to life

(b) describe the structure and properties of enzymes including their role as catalysts in catabolic and anabolic reactions (both intracellular and extracellular)

(c) explain the specificity of enzymes and the induced-fit mode of action

(d) describe, explain and investigate factors affecting enzyme kinetics including the effect of temperature, pH, substrate and enzyme concentration in terms of activation energy, kinetic energy, successful collisions, complementary shape and fit, as well as active site/substrate interactions including V_{max}

(e) describe end product inhibition and allosteric regulation (including phosphofructokinase and ATP)

(f) explain the impact of deficiency of phenylalanine hydroxylase (PAH) in the inherited disease phenylketonuria (PKU) and describe this as an example of a group of diseases termed inherited metabolic diseases

(g) describe and explain the effect of competitive and non-competitive inhibitors on enzyme activity

(h) explain the advantages of enzyme immobilisation

(i) outline commercial applications of using immobilised enzymes, including the production of lactose-free milk

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

Practical

Candidates should be able to:

(i) carry out investigations into the properties of a variety of enzymes in relation to the effect of temperature, pH, inhibitors and concentrations of enzyme and substrate

(ii) investigate the effect of immobilisation of enzymes on re-use of enzymes, ease of removal of enzyme from product and thermostability of enzymes.

1.5 Respiration

Content

- ATP
- chemiosmosis
- glycolysis
- anaerobic respiration in mammals, yeast and plants
- reactions within mitochondria

Candidates should be able to:

(a) explain the need to release energy to drive metabolic reactions and the role of ATP

(b) outline chemiosmosis as a system in prokaryotes and eukaryotes in which:
- electrons may gain energy from oxidation of chemical substrates and that this energy may be used to do work
- energetic electrons pass through the electron transport system to release energy
- the released energy is used to transfer protons out through 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

(c) outline glycolysis (phosphorylation to fructose 1,6-bisphosphate, hydrolysis to triose phosphate, oxidation and dephosphorylation to pyruvate)

(d) outline the link reaction and Krebs cycle within the mitochondrion, general principles of dehydrogenation and decarboxylation to produce ATP, and reduced NAD and FAD

(e) outline anaerobic respiration in animals limited to the oxidation of reduced NAD to regenerate NAD and conversion of pyruvate to lactate and compare this with anaerobic respiration in yeast and plants

(f) compare and contrast the energy released per molecule of glucose substrate in aerobic and anaerobic conditions and explain the reasons for the difference.

Practical

Candidates should be able to:

(i) investigate the rate of glucose respiration by yeast in aerobic and anaerobic conditions

(ii) investigate the effect of temperature on the rate of respiration using simple respirometers.

1.6 Genes and protein synthesis

Content

- the gene and genetic code
- protein synthesis
- control of gene expression
- inheritance and Mendelian genetics
- mutations
- genetic conditions

Candidates should be able to:

(a) define a gene as a unit of inheritance or 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 and discuss the limitations of these definitions with reference to introns, exons and promoters

(b) describe the genetic code and discuss the extent to which it is true that the code is universal to all organisms

(c) explain protein synthesis in terms of transcription and translation, including the roles of DNA, mRNA, tRNA and ribosomes

(d) describe, in outline, eukaryotic introns, exons and the splicing of mRNA

(e) define the term proteomics and outline its importance to biomedicine (limited to diagnosis and drug design)

(f) describe the control of gene expression in prokaryotes, including the roles of a regulator gene, repressor, promoter and operator in the transcription of structural genes

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

(h) define and use the terms allele, locus, phenotype, genotype, dominant, recessive and codominant

(i) use genetic diagrams to solve dihybrid crosses, including those involving sex linkage, autosomal linkage, epistasis, codominance and multiple alleles

(j) use and interpret the chi-squared test to test the significance of the difference between observed and expected results

Note: Candidates are not expected to recall the equations or symbols for the chi-squared test

(k) describe the effects of ionising radiation (high-energy UV, X-rays and emissions from radioactive decay) on living cells, including DNA damage that is repaired, DNA damage that leads to apoptosis, and DNA damage that causes mutations

(l) explain how some mutations can cause cancer, including those that cause proto-oncogenes to become oncogenes and those that reduce the activity of tumour suppressor genes

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

(n) explain, with reference to sickle cell anaemia and cystic fibrosis, how gene mutations might affect expression of a protein and thus affect phenotype (issues related to genetic conditions need to be handled with sensitivity).

Practical

Candidates should be able to:

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

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

1.7 Applications of cell biology

Content

- principles of genetic engineering
- isolating genes
- cloning DNA
- vectors and insertion into host cells
- identifying and cloning transformed cells
- gene therapy and genetic profiling (DNA fingerprinting)
- gene sequencing – methods and applications
- stem cells – isolation and uses
- ethical issues surrounding genetic engineering and the use of stem cells

Candidates should be able to:

(a) discuss the potential and actual advantages and disadvantages of transferring genetic material by genetic engineering compared to selective breeding

(b) explain strategies that are available to isolate the desired gene from the genome of the gene donor including:
- use of mRNA and reverse transcriptase
- use of restriction endonucleases to fragment the genome, and use of electrophoresis and complementary gene probes to identify relevant fragments from the gene

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

(d) 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, followed by uptake of the recombinant plasmid by a host cell
- use of *Agrobacterium tumefaciens* in inserting DNA into plant cells (e.g. in creating Golden Rice™ and Golden Rice 2)
- use of microprojectiles in inserting DNA into plant cells

(e) discuss the advantages and disadvantages of ways that have been used to identify transformed cells including antibiotic resistance genes and green fluorescent protein (GFP) genes

(f) outline how genes are inserted into target cells in gene therapy (limited to liposomes and viral vectors)

(g) explain the limitations, both potential and actual, of gene therapy as a treatment for genetic conditions (including cystic fibrosis and severe combined immunodeficiency [SCID])

(h) outline the processes used in genetic profiling (DNA fingerprinting) including the use of restriction endonucleases, amplification and electrophoresis visualisation (e.g. by fluorescently-tagged primers)

(i) describe methods of DNA sequencing (limited to the chain termination and the dye-terminator methods) and describe uses of this technology (to include the Human Genome Project and uses in taxonomy [molecular phylogenetics] and clinical diagnosis)

(j) describe how stem cells (zygotic, embryonic and adult) are obtained for research

(k) discuss the current and potential uses of stem cells (e.g. to replace damaged tissues, study aspects of development and cell chemistry, test new drugs, screen potentially toxic chemicals, facilitate gene therapy)

(l) discuss the ethical implications of the applications of genetic engineering and stem cells, including agricultural, industrial, research and medical applications.

Practical

Candidates should be able to:

(i) investigate aspects of genetic profiling including practical investigation of electrophoresis using dyes and DNA fragments

(ii) investigate transformation of bacteria, e.g. using the pGLO plasmid

(iii) investigate the *lac* operon using ONPG solution.

2 The origin and evolution of life

This section deals with the fundamental questions that help us define life – what materials and conditions are required for life to exist, when did it all get started, how are organisms changing and what drives this change?

2.1 The origins of life

Content

- origin of complex organic molecules
- origin of prokaryotic and eukaryotic cells
- advantages of multicellularity

Candidates should be able to:

(a) describe the evidence for a single origin of life in terms of conservation of key biochemical mechanisms including the genetic code and the ubiquitin/proteasome mechanism

(b) describe and explain how eukaryotes are thought to have originated about 2.7 billion years ago by endosymbiosis and the evidence that supports the theory of endosymbiosis

(c) discuss the benefits and disadvantages of being multicellular (including cell specialisation, division of labour and increased size and complexity with the necessity for coordination systems).

Practical

Candidates should be able to:

(i) use a microscope or photomicrographs to compare small multicellular eukaryotes (e.g. *Volvox*, rotifers, tardigrades) with unicellular eukaryotes (e.g. *Amoeba*, *Euglena*, ciliates).

2.2 The chemicals of life

Content

- water
- lipids
- carbohydrates
- proteins
- nucleic acids

Candidates should be able to:

(a) describe the chemical and physical properties of water and explain the biological significance of these properties

(b) describe the structures and properties of triglycerides and phospholipids and explain how these are related to their roles in living organisms

(c) describe the formation and breakage of ester bonds such as those found in triglycerides

(d) distinguish between saturated and unsaturated fatty acids

(e) describe the structures and properties of monosaccharides (α- and β-glucose and ribose), disaccharides (maltose and sucrose) and polysaccharides (amylose, amylopectin, cellulose and glycogen), and explain how these are related to their roles in living organisms

(f) describe the formation and breakage of glycosidic bonds

(g) describe the structures and properties of amino acids, globular proteins (including enzymes and haemoglobin) and fibrous proteins (limited to collagen), and explain how these are related to their roles in living organisms

(h) describe the formation and breakage of peptide bonds

(i) distinguish between the primary, secondary, tertiary and quaternary structure of proteins

(j) explain the significance of primary, secondary, tertiary and quaternary structure as well as hydrogen, ionic, peptide and disulfide bonding and hydrophobic interactions in giving the shape of 3D globular proteins (tertiary and quaternary structures)

(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).

Practical

Candidates should be able to:

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

(ii) 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

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

2.3 The evolution of life

Content

- selection and changes in allele frequency
- speciation
- aspects of evolution

Candidates should be able to:

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

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

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

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

(e) discuss what effect increased environmental stress, such as that caused by climate change, might have on the proportion of niches that are occupied and the implication of this for evolutionary change

(f) discuss the difference between background extinction and mass extinction, and the extent to which human activities are contributing to extinction

(g) 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)

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

Practical

Candidates should be able to:

(i) investigate the relationship between aspects of the environment and features of species, such as banded snails (*Cepaea* spp.).

2.4 Classification

Content

- the species concept
- classification systems

Candidates should be able to:

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

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

(c) distinguish between phylogenetic (cladistic) and phenetic classification systems, and understand the general preference for phylogenetic systems

(d) describe the hierarchy of seven major taxonomic groups from kingdom to species with reference to the example of *Homo sapiens*

(e) discuss the extent to which the five kingdom and the three domain classification systems reflect evolutionary (phylogenetic) relationships and are useful to biologists.

Practical

Candidates should be able to:

(i) recognise key features of the different kingdoms from specimens, photographs and drawings

(ii) use dichotomous keys to identify organisms from different taxa.

3 Animal physiology

Section 3 (Animal physiology) and Section 4 (The life of plants) take a look at life in terms of whole organisms.

Animal physiology explores the different ways in which animals feed, reproduce and transport substances around their bodies, highlighted by differences due to adaptation and a constantly changing environment.

3.1 Transport systems

Content

- structure and function of transport systems in multicellular animals
- ventilation mechanisms
- the mammalian circulatory system
- oxygen transport in the blood

Candidates should be able to:

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

(b) explain the need for mass flow systems in animals

(c) compare ventilation mechanisms and gas exchange in insects, fish and mammals

(d) discuss the advantages and disadvantages of:
- open and closed transport systems
- single and double circulatory systems with reference to the increasing complexity and efficiency of circulatory systems of fish, amphibians and mammals

(e) describe the relationship between the structure and function of mammalian arteries, veins and capillaries

(f) describe the structure and function of the components of mammalian blood, including the role of erythrocytes in oxygen and carbon dioxide transport, platelets in clotting, and lymphocytes, neutrophils and monocytes/macrophages in the immune response

(g) explain the functions of blood (limited to clotting and the transport of oxygen and carbon dioxide)

(h) explain the significance of oxygen-haemoglobin dissociation curves and the Bohr effect

(i) describe the structure of the mammalian heart, its electrical coordination and the pressure changes that occur during the cardiac cycle

(j) explain how heart rate is controlled by the medulla oblongata, including the roles of chemoreceptors and baroreceptors

(k) outline the roles of low-density lipoprotein (LDL) and high-density lipoprotein (HDL) in metabolism and transport of lipids and in atherosclerosis

(l) outline the aetiology of coronary heart disease (CHD) as an example of a cardiovascular disease

(m) outline the roles of drugs (limited to warfarin and statins) and surgery (limited to valve replacements, by-pass surgery, transplants and stents) in treatment of cardiovascular disease.

Practical

Candidates should be able to:

(i) observe the similarities and differences between mammalian blood cells, limited to erythrocytes, lymphocytes, neutrophils and monocytes

(ii) investigate the tracheal system of an insect (e.g. locust), the gills of a fish and the trachea and lungs of a mammal

(iii) explain the relationship between the structure and function of the mammalian heart and blood vessels (artery, vein and capillary) using prepared slides.

3.2 Nutrition

Content

- modes of nutrition
- mammalian alimentary canal and digestion

Candidates should be able to:

(a) compare and contrast the modes of nutrition, dentition and digestive systems of non-ruminant herbivores and carnivores

(b) recall the structure and function of the mammalian alimentary canal, including the histology of the stomach, ileum and pancreas

(c) identify sites of production, activation and action of the following enzymes in humans as an example of a mammal: amylase, maltase, endopeptidases (including pepsin and trypsin), exopeptidases and lipase

(d) explain the parts played by bile, mucus and sodium hydrogencarbonate in digestion.

Practical

Candidates should be able to:

(i) explain the relationship between the structure and function of the mammalian stomach, ileum, liver and pancreas (exocrine and endocrine tissues) using histological sections and electron micrographs.

3.3 Nerves, muscles and behaviour

Content

- the nervous system
- nerves and synapses
- the brain
- muscles
- innate and learned behaviour
- social behaviour in primates

Candidates should be able to:

(a) describe the organisation of the central and peripheral nervous systems to include a transverse section of the spinal cord

(b) describe the structure and function of sensory and motor neurones

(c) describe the production of the resting potential and the generation and transmission of action potentials in myelinated and unmyelinated neurones

(d) discuss the factors affecting the speed of impulse transmission in neurones (limited to neurone diameter, body temperature and myelination)

(e) describe and explain transmission at chemical synapses including antagonistic, excitatory and inhibitory neurotransmitters as exemplified by acetylcholine, noradrenaline and GABA

(f) 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)

(g) describe the structure and functioning of the neuromuscular junction and propagation of the action potential across muscle cells

(h) describe the histology and ultrastructure of striated muscle and relate this to its contraction

(i) describe and explain the sliding filament theory of muscle contraction to include the roles of calcium ions, ATP, actin, myosin, troponin and tropomyosin

(j) explain the advantages of innate and learned behaviours to organisms

(k) describe examples of genetically determined innate behaviours including taxes, kineses, and instinctive behaviours

(l) describe examples of learned behaviours widespread in the animal kingdom including habituation, imprinting, classical conditioning and operant conditioning

(m) describe examples of social behaviour in primates and discuss the advantages of such behaviour.

Practical

Candidates should be able to:

(i) explain the relationship between the structure and function of the spinal cord, brain (cerebral hemispheres and cerebellum only), nerves, myelinated neurones, synapses, neuromuscular junctions and striated muscle using histological sections and electron micrographs

(ii) investigate innate behaviour using choice chambers and suitable motile invertebrates

(iii) use simple T-mazes to investigate operant conditioning using suitable motile invertebrates.

3.4 Homeostasis and cell signalling

Content

- homeostasis
- regulatory hormones
- the roles of the liver in homeostasis
- the roles of the kidney and hypothalamus in homeostasis
- cell signalling

Candidates should be able to:

(a) define homeostasis as the ability to maintain a dynamic equilibrium resulting in a stable internal environment using negative feedback mechanisms

(b) describe the structure and function of the liver to include its role in blood sugar control, deamination, transamination and detoxification

(c) outline the actions of insulin and glucagon on cells, including the roles of membrane receptors, changes in membrane permeability to glucose and the synthesis and breakdown of glycogen in hepatocytes and muscle cells

(d) outline the causes, diagnosis, effects and treatment of type 1 and type 2 diabetes

(e) 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 multiplication

(f) describe the role of the hypothalamus, posterior pituitary and ADH in osmoregulation

(g) describe the role of the medulla oblongata in controlling the circulatory system [see also Section 3.1(j)]

(h) outline the principles of cell signalling in terms of:

- ligand-receptor interaction
- signal transduction
- enzyme cascade and amplification
- change in cell functioning

(i) outline the functioning of G-protein receptors in transduction of signals including increased extracellular ADH and glucagon concentrations.

Practical

Candidates should be able to:

(i) examine the gross structure of the kidney

(ii) examine the detailed structure of the nephron with associated blood vessels using histological sections and electron micrographs

(iii) investigate examples of homeostasis, such as control of heart rate and osmoregulation.

3.5 The immune system

Content

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

Candidates should be able to:

(a) contrast the specific and non-specific immune systems

(b) outline the roles of B lymphocytes (B cells, plasma cells and memory cells) and T lymphocytes (helper T cells, cytotoxic T cells and memory cells) in giving specific immune primary and secondary responses

(c) discuss the structure and action of antibodies (including variable and non-variable regions of the monomeric immunoglobulin, IgG, but not including the range of types and functions of immunoglobulins)

(d) distinguish between active and passive immunity, as well as natural and artificial immunity (limited to the examples of tetanus, TB, polio and measles)

(e) describe the cause and means of transmission of malaria and discuss its global impact and why it is difficult to control

(f) explain the term autoimmune disease with reference to type 1 diabetes and myasthenia gravis

(g) outline the ABO blood group system and discuss its implications in transfusion and hyperacute rejection of transplanted organs

(h) outline the principles involved in histocompatibility and acute transplant rejection (details of the MHC system are not required)

(i) outline the production of monoclonal antibodies and explain why it is necessary to use hybridoma cells for this purpose

(j) describe and explain the use of monoclonal antibodies in the direct and indirect ELISA test for the diagnosis of plant and animal diseases.

3.6 Reproduction

Content

- human sexual reproduction
- cloning

Candidates should be able to:

(a) explain the roles of ovarian and anterior pituitary hormones in controlling the menstrual cycle (limited to oestrogen, progesterone, FSH and LH)

(b) explain the roles of the placenta in pregnancy to include the transfer of materials, isolation of fetus from maternal blood and production of hormones (including chorionic gonadotrophin, oestrogen and progesterone and human placental lactogen)

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

(d) explain what cloning is and discuss ethical issues relating to the use of cloning in animals and humans (including production of cattle and therapeutic cloning).

Practical

Candidates should be able to:

(i) explain the relationship between the structure and function of the mammalian testis and ovary (including follicles and corpus luteum) using histological sections and electron micrographs.

[see also Section 1.3 Practical (iii)]

4 The life of plants

Plants provide us with the material to study many biological principles. We ignore them at our peril as they are the foundation of almost all food chains and provide us, directly or indirectly, with most of our food and many economically important products. This section explores several aspects of their physiology – from their highly adaptable transport systems to the great variety of methods of reproduction and ultimate reliance on sunlight.

4.1 Transport in plants

Content

- transport of water in the xylem
- transport of assimilates in the phloem
- stomata – structure and function

Candidates should be able to:

(a) describe the passage of water through a dicotyledonous plant from soil to atmosphere

(b) describe the structure and function of the xylem of flowering plants and explain the relationship between its structure and functions

(c) explain the role of cohesion-tension in the transport of water in the xylem

(d) describe the structure and function of guard cells

(e) explain the mechanism of opening and closing of stomata

(f) describe the structure and function of phloem tissue and explain the relationship between its structure and function

(g) describe the mechanism of loading phloem sieve tubes and mass flow in phloem from source to sink.

Practical

Candidates should be able to:

(i) explain the relationship between the structure and function of xylem and phloem using histological specimens from plant transport systems including prepared slides and electron micrographs.

4.2 Photosynthesis

Content

- light-dependent stage
- light-independent stage
- photorespiration

Candidates should be able to:

(a) explain the relationship between the light-dependent and light-independent stages of photosynthesis within the chloroplast of a C3 plant

(b) describe the use of 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 that electrons may gain energy from sunlight and that this energy may be used to do work

(e) explain the production of ATP and reduced NADP during the light-dependent stage (including roles of photosystems I and II, electron transport chain, generation of proton gradient, cyclic and non-cyclic photophosphorylation)

(f) 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)

(g) outline the use of Calvin cycle intermediates to generate a range of organic molecules

(h) discuss the importance of the enzyme rubisco and its vulnerability to competitive inhibition by oxygen during photorespiration

(i) outline the impact of high light intensities and temperatures on the rate of photorespiration

(j) explain, in outline, how C4 plants reduce the impact of photorespiration by isolating the light-independent stages from the oxygen in the air, limited to the means used to produce spatial separation. (Biochemical details of the C4 pathway are not required.)

Practical

Candidates should be able to:

(i) investigate the Hill reaction using a chloroplast suspension and DCPIP

(ii) investigate the structure of chloroplasts using electron micrographs

(iii) carry out paper or thin layer chromatography to separate and identify key photosynthetic pigments

(iv) compare the leaf anatomy of C3 (e.g. *Ligustrum*, *Triticum*) and C4 (e.g. *Zea mays*) plants under the light microscope.

4.3 Reproduction

Content

- pollination
- fertilisation
- seeds and fruit

Candidates should be able to:

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

(b) 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
- chemotropic growth of pollen tube to embryo sac

(c) outline the role of meiosis in the development of pollen and embryo sacs and of mitosis in the formation of gametes

(d) explain the significance of double fertilisation in flowering plants and describe the development of seeds and fruits (including one endospermous seed and one non-endospermous seed).

Practical

Candidates should be able to:

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

(ii) investigate a variety of flowers showing a range of adaptations (e.g. wind pollination and insect pollination)

(iii) investigate the structure of seeds and fruits using specimens of endospermous seeds, such as maize, and non-endospermous seeds, such as those of legumes

(iv) investigate seed and fruit development using fresh specimens and prepared slides of Shepherd's purse, *Capsella bursa-pastoris*.

4.4 Control of plant processes

Content

Genetic control of plant cell growth

- role of membrane transporters in phototropism
- mode of action of gibberellins and auxins

Candidates should be able to:

(a) state that, in the absence of gibberellins or auxins, flowering plant cell growth is restricted by transcription blocking factors that block the transcription of genes responsible for cell growth

(b) describe how both gibberellins and auxins promote plant cell growth

(c) explain how gibberellins promote stem elongation in flowering plants by controlling cell elongation

(d) explain how mutant alleles for gibberellin synthesis have led to dwarf rice, and mutant alleles for synthesis of DELLA protein have led to dwarf wheat, in both cases increasing yield because a greater proportion of energy is put into grain

(e) explain the existence of Mendel's tall and dwarf pea plants in terms of a pair of alleles, the dominant allele, *Le*, coding for a functioning enzyme in the gibberellin synthesis pathway, the recessive allele, *le*, coding for a non-functional enzyme

(f) explain the role of auxins in positive phototropism of stems.

Practical

Candidates should be able to:

(i) investigate phototropism in coleoptiles or other young shoots including unilateral application of auxin from excised coleoptile tips or auxin in a gel

(ii) investigate the effect of gibberellins on dwarf/bush pea or sweet pea seedlings

(iii) investigate whether plants with a basal rosette of leaves have non-functional gibberellin genes, by adding gibberellins.

5 Environmental studies

This section deals with life on a global scale – the interactions between life and the environment. It takes a look at the huge variety of life and why organisms live in the places they do. The section also considers the impact of climate change and the ways in which we are able to protect and conserve biodiversity.

This section 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 in outcomes 5.1 (a) and (b) 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).

5.1 Adaptation

Content

- adaptation and the ecological niche

Candidates should be able to:

(a) explain what is meant by the term adaptation by reference to specific physiological and behavioural adaptations of a named bird (e.g. starling or dunnock) and a motile protoctist (e.g. a ciliate or a motile photosynthetic protoctist)

(b) discuss how the niche concept and adaptation explain the distribution of organisms within habitats

(c) explain how an individual's adaptive behavioural strategy can vary within a species, with particular reference to the dunnock

(d) explain the global distribution of C3 and C4 plants and discuss the potential impact of climate change on future patterns of agriculture

(e) describe and explain adaptations characteristic of hydrophytes and xerophytes and apply biological principles to consider the significance of adaptations of flowering plants living in a variety of other habitats.

Practical

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) study leaves from flowering plants adapted to a variety of habitats, including hydrophytes (e.g. *Nymphaea* or *Nuphar*) and xerophytes (e.g. *Erica* or *Nerium*).

5.2 Measuring and conserving biodiversity

Content

- biodiversity
- sampling techniques as ecological tools
- principles of conserving biodiversity
- the species-area concept
- integrated management strategies

Candidates should be able to:

(a) explain what is meant by biodiversity with reference to different levels: ecosystem, community, species and genetic

(b) use, or interpret secondary data from, quantitative and qualitative techniques for measuring biodiversity and abundance, including diversity indices, percentage cover, species density, direct counts and relative abundance scales (e.g. ACFOR)

(c) explain how to estimate population size using mark-release-recapture and the Lincoln index

(d) discuss the importance of conservation and the types of information needed to inform conservation strategies

(e) explain the concept of the keystone species and discuss the consequences of the loss of such species on biodiversity

(f) discuss the importance of conserving biodiversity for social, ethical, medical, economic and environmental reasons

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

(h) discuss the implications of the species-area concept in conservation strategies including the danger of habitat fragmentation and the importance of corridors

(i) discuss the SLOSS debate (Single Large Or Several Small reserves).

Practical

Candidates should be able to:

(i) undertake an ecological survey of at least one ecosystem using appropriate methods, such as open and grid quadrats, point quadrats, line transect, belt transect and methods for measuring abiotic factors

(ii) determine the diversity of an ecosystem by calculating Simpson's index of diversity or another appropriate index

Note: Candidates are not expected to recall the equations or symbols for indices of diversity

(iii) determine the population of a small animal using the mark-release-recapture method and calculate the Lincoln index (alternatively this may be modelled).

6 Practical biology

6.1 Planning and decision making

6.1.1 Defining the problem

Candidates should be able to:

(a) identify the dependent and independent variables in an investigation or experiment

(b) express the aim in terms of a prediction or hypothesis, and express this in words and, if appropriate, in the form of a predicted graph

(c) identify the variables that are to be controlled

(d) decide on a control experiment or experiments (if appropriate).

6.1.2 Choosing appropriate techniques

Candidates should be able to:

(a) describe the method to be used to vary the independent variable, and the means to ensure that its values are measured accurately

(b) describe how the dependent variable is to be measured

(c) describe how each of the other key variables is to be controlled

(d) 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

(e) describe the arrangement of apparatus and the steps in the procedure to be followed

(f) suggest appropriate volumes and concentrations of reagents, and explain how different concentrations should be prepared [including %(w/v), mol dm^{-3}, serial dilution and proportional dilution]

(g) assess the risks of their proposed methods

(h) describe precautions that should be taken to keep risks to a minimum

(i) draw up tables for data that they might wish to record

(j) describe how the data might be used in order to reach a conclusion.

6.1.3 Determining number of measurements and/or observations to take

Candidates should be able to:

(a) choose a suitable range of values for the independent variable in an investigation

(b) choose a suitable number of intermediate values for the independent variable

(c) decide how many replicates to take of each value of the independent variable to ensure validity of results

(d) decide how many observations to take in an investigation that generates qualitative data.

6.2 Manipulation, measurement and observation

6.2.1 Successful collection of data and observations

Candidates should be able to:

(a) set up apparatus correctly

(b) follow instructions given in the form of written instructions, flow charts or diagrams

(c) use their apparatus to collect an appropriate quantity of data or observations, including subtle differences in colour or other properties of materials

(d) make measurements using millimetre scales, graticules, protractors, stopwatches, balances, measuring cylinders, syringes, thermometers, and other common laboratory apparatus

(e) use a light microscope correctly including adjustment of lighting, focusing on specimens with an objective lens at both low power (×10) and high power (×40) and making measurements with a graticule fitted into the eyepiece.

6.2.2 Decisions about measurements or observations

While carrying out an investigation, candidates should be able to:

(a) decide how many tests, measurements or observations to perform

(b) make measurements or observations that span the largest possible range within the limits either of the equipment provided or of the instructions given

(c) make qualitative observations and/or quantitative measurements that are appropriately distributed within this range

(d) decide how long to leave experiments running before taking readings

(e) replicate observations, readings or measurements as necessary

(f) make and record sufficient, accurate measurements and observations.

6.3 Presentation of data and observations

6.3.1 Recording data and observations in tables and other suitable forms

Candidates should be able to:

(a) present numerical data, values or observations in a single table of results

(b) draw up the table before taking readings/making observations, so that these can be recorded directly into the table, avoiding the need to copy up the results

(c) make tables of data and observations large enough so that all the entries can be comfortably fitted in the available space

(d) include in the table of results, if necessary, columns for raw data, for calculated values and for deductions

(e) use column headings that include the quantity and the unit (as appropriate) and that conform to accepted scientific conventions

(f) record raw readings of a quantity to the same degree of precision and observations to the same level of detail

(g) follow the Society of Biology recommendations for constructing tables

(h) make drawings large and un-shaded so that errors are small, and use fine, clear, unbroken lines, showing clear outlines of structures

(i) use pencil for drawings and lines on tables.

6.3.2 Presenting data in the form of graphs and charts

Candidates should be able to:

(a) present data in the form of charts, graphs, drawings or mixtures of methods of presentation

(b) select the most appropriate form of presentation for the data collected or provided, e.g. bar chart, histogram and line graph

(c) select which variable(s) to plot and plot appropriately on clearly labelled *x*- and *y*-axes

(d) plot all points or bars to an appropriate accuracy

(e) follow the Society of Biology recommendations for putting lines on graphs.

6.4 Analysis of data and conclusions

6.4.1 Display of calculations and reasoning

Candidates should be able to:

(a) show their working in calculations, and the key steps in their reasoning

(b) use the correct number of significant figures for calculated quantities.

6.4.2 Description of patterns and trends

Candidates should be able to:

(a) use tables and graphs to draw attention to the key points in quantitative data, including the variability of data

(b) describe the patterns and trends shown by data in tables and graphs

(c) describe and summarise the key points of a set of observations.

6.4.3 Interpretation of data and observations

Candidates should be able to:

(a) identify and carry out the calculations that are necessary to be able to draw conclusions from primary and/or secondary data (limited to determination of mean, median, mode, percentage, rate of reaction and magnification)

(b) use descriptive statistics (limited to range, interquartile range, percentiles, standard deviation and standard error) to simplify data, assess its variability and determine the confidence in the validity of conclusions

Note: Candidates are not expected to recall the equations or symbols for standard deviation and standard error

(c) use appropriate statistical tests (limited to *t*-test and chi-squared test) to determine goodness of fit and the statistical differences between samples

Note: Candidates are not expected to recall the equation or symbols for the *t*-test and chi-squared test

(d) find an unknown value by using co-ordinates or axis intercepts on a graph or a calibration curve

(e) 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

(f) determine the gradient of a straight-line graph or tangent to a curve

(g) put error bars on graphs, which may be calculated using standard error

(h) use Spearman's rank and Pearson's linear correlation to test for correlation

Note: Candidates are not expected to recall the equations or symbols for Spearman's rank and Pearson's linear correlation.

6.4.4 Making conclusions drawing on theoretical knowledge and understanding

Candidates should be able to:

(a) 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 support a given hypothesis or not

(b) make detailed scientific explanations of the data and of their conclusions

(c) make further predictions and suggest informed and relevant questions.

6.5 Evaluation of procedures and data

6.5.1 Identifying limitations and sources of error

Candidates should be able to:

(a) make criticisms of the experimental procedure

(b) evaluate the effectiveness of control of variables and thus the confidence with which conclusions might be drawn

(c) identify the most significant sources of error in an experiment

(d) estimate, quantitatively, the uncertainty in quantitative measurements

(e) express such uncertainty in a measurement as an actual or percentage error

(f) show an understanding of the distinction between systematic errors and random errors

(g) identify anomalous values in provided data and suggest appropriate means of dealing with such anomalies

(h) within familiar contexts, suggest possible explanations for anomalous readings

(i) identify the extent to which provided readings have been adequately replicated, and describe the adequacy of the range of data provided

(j) use provided information to assess the extent to which selected variables have been effectively controlled

(k) use these evaluations and provided information to make informed judgements on the confidence with which conclusions may be drawn.

6.5.2 Suggesting improvements

Candidates should be able to:

(a) 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

(b) describe such modifications clearly in words or diagrams.

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 finding and using 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, ≈, /, ∝, Σ
- calculate areas of triangles, circumferences and areas of circles, and surface areas and volumes of rectangular blocks and cylinders
- translate information between graphical, numerical, and algebraic forms
- construct and interpret frequency distributions 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
- understand, draw and use the slope of a tangent to a curve as a means to obtain 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 (straight or curved) of best fit
- choose, by inspection, a line (straight or curved) which will serve as the line of best fit through a set of data points presented graphically
- understand and use the prefixes: giga (G), mega (M), kilo (k), milli (m), 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 a spreadsheet program for collating, analysing and presenting data
- find the median, mode, total range and interquartile range and understand percentiles
- calculate standard deviation and standard error*
- understand the benefits of using standard error and 95 per cent confidence intervals (95%CI) to make statements about data and to use as error bars on graphs
- understand the difference between correlation and causation
- use Spearman's rank and Pearson's linear correlation to test for correlation*
- use the chi-squared test and the *t*-test*

Electronic calculators will be permitted in the examination, subject to Cambridge general regulations.

*Note: Candidates are not expected to recall the equations or symbols for standard deviation, standard error, Spearman's rank correlation, Pearson's linear correlation, chi-squared test and *t*-test.

Guidance on practical work and 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 per cent of their time doing practical work individually or in small groups. This 20 per cent 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 and rewarding.

The planning aspect of practical assessment is examined in Component 2 (along with data analysis, interpretation and evaluation). All other aspects of pratical assessment are through Component 4, the practical examination paper.

It should be stressed that candidates cannot be adequately prepared for planning, data analysis, interpretation and evaluation in Component 2 and the practical examination in Component 4 without extensive laboratory work during their course of study, under careful supervision from teachers to ensure that experiments are conducted with due regard to safety.

Throughout their course, candidates should therefore be given opportunities to make decisions about their practical work including the range and number of values of the independent variable, the number of repeats, and the provision of controls. They should also plan complete experiments to include methods of data collection and analysis. Candidates should keep records of the practical work they carry out during their course.

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 and make appropriate decisions on their application. 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
- following instructions to use unfamiliar biochemical procedures
- making microscopic observations, drawings and magnification calculations from unfamiliar structures or specimens
- making observations and deductions from photographs, photomicrographs, electron micrographs and specimens.

Component 4 will consist of two sections, A and B. Both sections will be laboratory-based practicals requiring skills of experimentation, observation, presentation, analysis, deduction and evaluation.

For both Section A and Section B, some questions may include secondary data, particularly if they are 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 Biology syllabus. Information that candidates are not expected to know, but is needed to allow them 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.

Candidates may start with Section A or Section B. They will need the use of a microscope in Section B for at least 35 minutes, or as specified in the Confidential Instructions, up to a maximum of 60 minutes. The timings for the questions are recommended timings. Candidates should be advised not to spend longer on each question than the timings given on the examination paper.

Section A will consist of one or two questions totalling 45 marks. It should be completed in about 90 minutes. It will include an experiment or experiments requiring candidates to collect quantitative or qualitative data, draw up tables, charts, graphs or other appropriate means of presenting the data, analyse data, draw appropriate conclusions and evaluate procedures and data.

It will focus on the following experimental skills:

- manipulating apparatus
- decision making
- recording observations and measurements
- presenting data
- calculating, e.g. rates of reaction
- analysing data – describing experimental results, observations and secondary data
- concluding
- evaluating procedures and data
- suggesting improvements.

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 about how practical examinations should be set up, it is vital that Centres contact Cambridge as soon as possible.

Frequently required apparatus and materials are detailed later in the syllabus. Candidates should be accustomed to using these. However, to give some variation in the questions set, some novel items may be required at times.

Section B will consist of one or more short questions totalling 35 marks. It should be completed in about 60 minutes. The questions will test the candidates' abilities to make observations and present, analyse and interpret their findings. Candidates will be expected to use a microscope to observe and draw from histological specimens that either they have made themselves as temporary mounts or are provided as prepared slides. Candidates will also be provided with secondary data to analyse and interpret. This secondary data may be in the form of photographs, drawings, diagrams, tables and graphs. Section B will concentrate on the following skills:

- decision making
- observing

- presenting information in the form of plan diagrams, drawings, tables, etc.
- calculating, e.g. magnifications and actual sizes
- analysing data – describing and interpreting experimental results, observations and secondary data
- evaluating.

Assessment of skills in Components 2 and 4

Practical assessment will involve the testing of five skill areas. Each skill area is divided into relevant sub-skills. Details of the sub-skills are given in the Syllabus content section of the syllabus.

Skill	Sub-skills
Planning and decision making	• defining the problem • choosing appropriate techniques • determining number of measurements/observations to take
Manipulation, measurement and observation	• successful collection of data and observations • decisions about measurement or observations
Presentation of data and observations	• recording data and observations in tables and other suitable forms • presenting data in the form of graphs and charts
Analysis of data and conclusions	• display of calculation and reasoning • description of patterns and trends • interpretation of data and observations • making conclusions drawing on theoretical knowledge and understanding
Evaluation of procedures and data	• identifying limitations and sources of error • suggesting improvements

Apparatus and materials list

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.

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 ×6, preferably ×10)
forceps
scissors
mounted needles
cutting implement, e.g. solid-edged razor blade/knife/scalpel
mortars and pestles
suitable eye protection
microscope and lamp/inbuilt illumination with high-power and low-power objective lenses (one each or one between two candidates)
eyepiece graticules and stage micrometers
bench lamp with flexible arm
balance (0.01 g precision)
water-baths or equivalent
cork borers
stop clock/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

Chemicals and reagents

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

The following codes are used where relevant.

C	corrosive	**MH**	moderate hazard
HH	health hazard	**T**	acutely toxic
F	flammable	**O**	oxidising
N	hazardous to the aquatic environment		

[**N**] – iodine in potassium iodide solution
[**MH**] [**N**] – Benedict's solution
[**C**] [**MH**] – biuret reagent/potassium hydroxide and copper sulfate solution
[**F**] [**MH**] [**HH**] – ethanol (for fats test)
[**F**] [**MH**] [**HH**] – methylated spirit (extraction of chlorophyll)
sucrose (use AR for non-reducing sugar test)
glucose
starch
[**C**] [**MH**] – potassium hydroxide
sodium chloride
dilute hydrochloric acid
hydrogencarbonate indicator
sodium hydrogencarbonate
[**MH**] – limewater
distilled/deionised water
Universal Indicator paper and chart
litmus paper
neutral red solution or powder
[**MH**] – eosin/red ink
[**HH**] – methylene blue
Vaseline/petroleum jelly (or similar)
DCPIP (2,6–dichlorophenol-indophenol)
ascorbic acid (vitamin C)
[**HH**] – enzymes: amylase, trypsin (or bacterial protease), pepsin, pectinase
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. [**MH**] [**N**] copper sulfate)
stains for preparing slides to show mitosis – e.g. carmine acetic, toluidine blue, aceto-orcein
[**HH**] – Feulgen stain (Schiff's reagent)
[**HH**] – reagents for Gram staining – solutions of crystal violet, Gram's iodine and safranin
reagents for paper or thin layer chromatography
nutrient broth, nutrient agar
reagents and enzymes for investigation of the *lac* operon
reagents, materials and apparatus required for investigations using DNA and electrophoresis
[**C**] [**MH**] [**N**] – appropriate disinfectants
gibberellin, auxin

Ecological/fieldwork equipment

apparatus for sampling, e.g. 'open' and 'grid' quadrats, point quadrats
apparatus for measuring abiotic factors, e.g. oxygen meter, flow meter, light meter, etc.
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

Specimens

flowers of monoecious and dioecious species
flowers and pollen of wind-pollinated and insect-pollinated plants
seeds of a C3 plant and of a C4 plant
cereal seed
dwarf/bush pea or sweet pea seeds
variety of endospermous seeds and non-endospermous seeds
cultures of live yoghurt
appropriate cultures of microorganisms, e.g. *Escherichia coli*, *Bacillus subtilis*
insect (e.g. locust or cockroach), fish (complete or head only), and mammalian trachea and lungs to investigate gas exchange systems
examples of animal and plant cells/tissues to use for temporary mounts
examples of organisms representing the three kingdoms that are not animals or plants:

- Protoctista (e.g. *Amoeba*, *Euglena*, *Paramecium*, *Vorticella* 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

Prepared microscope slides

mitosis and meiosis
anther and ovule
VS fruit of *Zea mays*, VS fruit of *Capsella* or other plant with non-endospermous seeds
TS stem, TS root and TS leaf of a dicotyledonous mesophyte (e.g. *Ligustrum* or *Prunus* or local equivalent)
TS stem, TS leaf of a dicotyledonous hydrophyte (e.g. *Nuphar*, *Nymphaea* or local equivalent)
TS leaf of a xerophyte (e.g. *Erica*, *Ammophila*, *Nerium* or local equivalent)
stomach and ileum
pancreas and pituitary gland
heart, arteries, veins and capillaries
mammalian blood smear
liver
kidney
TS spinal cord, cerebral hemispheres, cerebellum, nerves
teased myelinated neurones
teased fibres of striated muscle and motor neurone endings
ovary, testis and placenta
TS leaf of a C4 plant, e.g. *Zea mays*

Safety in the laboratory

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

European Regulations

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

UK Regulations

Control of Substances Hazardous to Health Regulations (COSHH) 2002 (as amended). A brief guide may be found at: http://www.hse.gov.uk/pubns/indg136.pdf

Associations

CLEAPSS is an advisory service providing support in science and technology, primarily for UK schools: http://www.cleapss.org.uk

Independent and international schools and post-16 colleges can apply for associate membership which includes access to the CLEAPSS publications listed below.

Publications

CLEAPSS Hazcards (see annually updated CLEAPSS Science publications CD-ROM)
CLEAPSS Laboratory handbook (see annually updated CD-ROM)
CLEAPSS Recipe cards (see annually updated CD-ROM)
Safeguards in the School Laboratory, ASE, 11th Edition, 2006
Topics in Safety, ASE, 3rd Edition, 2001
ASE Safety reprints, 2006 or later
Hazardous Chemicals: A Manual for Science Education, SSERC, 1997
Hazardous Chemicals. An interactive manual for science education, SSERC, 2nd edition 2002 (CD2)

Notes on the use of statistics in biology

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

Type of variable	Type of data
Qualitative	
Categoric	Nominal
Ordered	Ordinal (ranked)
Quantitative	
Continuous	Interval (having any value, e.g. 1.0, 2.5, etc.)
Discrete	Interval (integers only, e.g. 1, 2, 3, etc.)

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

Candidates should know when it is appropriate to use a statistical test. They should be able to use statistical tests to test for an association and know when to test for the significance of differences between samples. The chi-squared (χ^2) test is used to test the difference between observed and expected frequencies of nominal data. The chi-squared test allows the evaluation of the results of breeding experiments and ecological sampling. The *t*-test is of value in much of biology to test for the significance of differences between samples. Candidates should be able to use Pearson's linear correlation to test for a correlation between two sets of normally-distributed data and Spearman's rank correlation to test for a correlation between two sets of data that are not distributed normally. They should know that a correlation does not necessarily imply a causative relationship.

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 and standard errors (which they may use for 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 when appropriate. In both the *t*-test and the chi-squared test they should be able to calculate the number of degrees of freedom. They should appreciate levels of significance and use calculated (or given) values of t and χ^2 to make appropriate conclusions.

standard deviation	$s = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$	
standard error	$S_M = \frac{s}{\sqrt{n}}$	
t-test	$t = \frac{\lvert\bar{x}_1 - \bar{x}_2\rvert}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$	$v = n_1 + n_2 - 2$
chi-squared test	$\chi^2 = \sum\frac{(O-E)^2}{E}$	$v = c - 1$

Key to symbols

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

Candidates are not expected to appreciate the difference between the population standard deviation, s_n (σ_n), and the sample standard deviation, s_{n-1} (σ_{n-1}). Chi-squared tests will only be expected on one row of data.

Questions involving the use of descriptive statistics and the statistical tests described above may be set on all components.

Glossary of terms used in biology papers

It is hoped that this 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)…) requires only a formal statement or equivalent paraphrase.

2 *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.

4 *List* requires a number of points with no elaboration. Where a given number of points is specified, this should **not** be exceeded.

5 *Explain* may imply reasoning or some reference to theory, depending on the context.

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 relevant, reference should be made to numbers drawn from the stimulus material.

(b) *Describe* a process, requires the candidate to give a step by step account of what happens during the process. *Describe* and *explain* may be coupled, as may *state* and *explain*.

7 *Discuss* requires the candidate to give a critical account of the points involved in the topic.

8 *Comment* is intended as an open-ended instruction, inviting candidates to recall or infer points of interest relevant to the context of the question, taking account of the number of marks available.

9 *Outline* implies that only the essential points are required, without any supporting detail.

10 *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.

11 *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 select the correct response.

12 *Suggest* is used in two main contexts:

(a) to imply that there is no unique answer (e.g. in biology, there are several factors that might limit the rate of photosynthesis in a plant in a glasshouse),

(b) to imply that candidates are expected to apply their general knowledge and understanding of biology to a 'novel' situation – many data response and problem-solving questions are of this type.

13 *Find* is a general term that may variously be interpreted as *calculate*, *measure*, *determine*, etc.

14 *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 relevant.

15 *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a ruler, or mass, using a balance. Suitable units should be given where relevant.

16 *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.

17 *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.

18 *Show* may be used when an algebraic deduction has to be made to prove a given equation. It is important that the algebraic symbols being used by candidates are stated explicitly. It may also indicate that the intervening steps in a logical process need to be stated or described.

19 (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. 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 representation of important details.

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

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 as to how much detail to give, e.g. the number of steps to include, or how much detail to give for each step.

Additional information

Equality and inclusion

This syllabus complies with our *Code of Practice* and *Ofqual General Conditions of Recognition*.

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

The standard assessment arrangements may present unnecessary barriers for candidates with disabilities or learning difficulties. Arrangements can be put in place for these candidates to enable them to access the assessments and receive recognition of their attainment. Access arrangements will not be agreed if they give candidates an unfair advantage over others or if they compromise the standards being assessed. Candidates who are unable to access the assessment of any component may be eligible to receive an award based on the parts of the assessment they have taken. Information on access arrangements is found in the *Cambridge Handbook (UK)*, for the relevant year, which can be downloaded from the website **www.cie.org.uk/examsofficers**

Guided Learning Hours

Cambridge Pre-U syllabuses are designed on the assumption that learners have around 380 guided learning hours per Principal Subject over the duration of the course, but this is for guidance only. The number of hours may vary according to local curricular practice and the learners' prior experience of the subject.

Total qualification time

This syllabus has been designed on the assumption that the total qualification time per subject will include both guided learning and independent learning activities. The estimated number of guided learning hours for this syllabus is 380 hours over the duration of the course. The total qualification time for this syllabus has been estimated to be approximately 500 hours per subject over the duration of the course. These values are guidance only. The number of hours required to gain the qualification may vary according to local curricular practice and the learners' prior experience of the subject.

If you are not yet a Cambridge school

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

Language

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

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