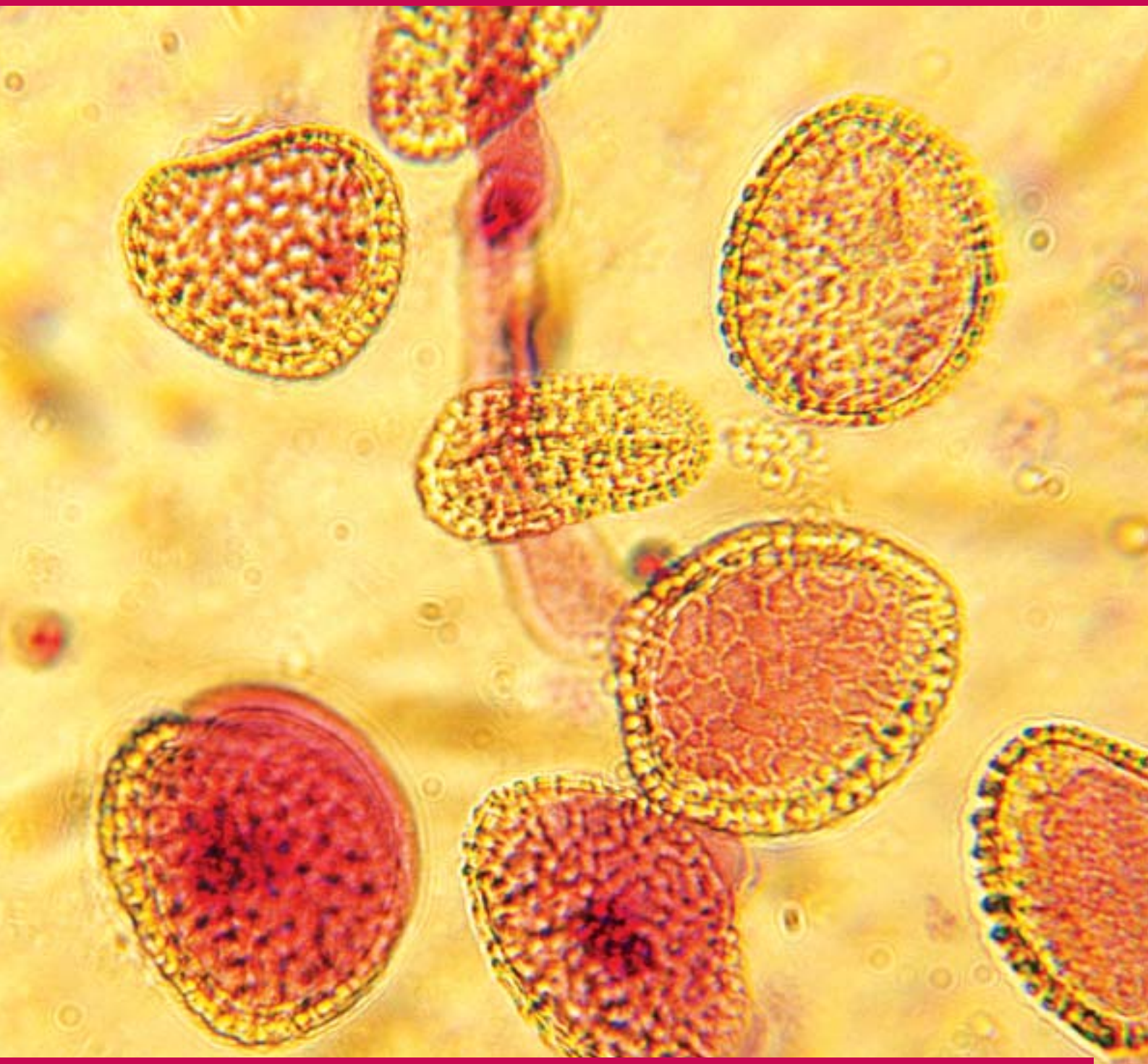
Cambridge Pre-U Teacher Guide

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

Available for teaching from September 2011



UNIVERSITY of CAMBRIDGE
International Examinations

Cambridge International Level 3 Pre-U Certificate

Biology

9790

Contents

"You may have been persuaded to study biology because of current environmental problems, or because of a desire to know more about the mechanisms of your own body, or an interest in genetic engineering, or a career in medicine – in short, because it is relevant…But above all other considerations, study biology because it is irrelevant – study it for its own sake, like art and music and literature…"

Helena Curtis

Introduction

This teacher guide has been written as support material for the Cambridge Pre-U Biology course. The aim has been to give an indication of the depth of knowledge required by this syllabus and to suggest possible examples that could be introduced in the classroom. Some teaching schemes have been included as well as guidance on some useful resources such as textbooks and websites. In no way does this guide tell teachers 'how to teach' the subject and it is not intended as a replacement for a textbook.

In most cases the depth of knowledge required is exactly the same as that found in most textbooks aimed at A Level students. The notes section of this guide may refer to students having a 'good level of understanding of this topic'. This in effect means the level expected from any good A Level textbook. Some areas may be less familiar to teachers or are areas not traditionally found in A Level texts. These are described in more detail with an indication of the depth required and possible examples. Unless stated in the syllabus, these examples are not exclusive and alternatives can of course be used.

Each Section of the syllabus is presented with the following features:

- the main topics in the section
- a series of leading questions to introduce each of the five major topics in the syllabus
- useful search terms for each subsection that may prove useful for teachers and students when carrying out research on the internet
- comments for each of the learning outcomes and also for each of the practical learning outcomes
- extension topics as suggestions for students to use in preparation for the essay in Paper 2

The learning outcomes represent the syllabus that will be examined. Students who wish to gain Distinction at Cambridge Pre-U Biology will be expected to show evidence of wider reading and research. The extension topics are included to offer some ideas of the directions that they might take, but they are suggestions and should not be seen as prescriptive. Similarly, such students are expected to further their study of practical biology beyond the limits set by the practical learning outcomes. They may wish to carry out their own research in the form of a long-term practical investigation. Biology may well become the focus of an extended project or an Individual Research Report.

For continued guidance, teachers should refer to the Principal Examiner Reports that are published after each examination session. Support and guidance are available on the Cambridge Teacher Support website at http://teachers.cie.org.uk/

Suggested Order of Teaching

The syllabus has not been written as a teaching sequence. Teachers and students have the freedom to plot their own course through the topics. Three suggested sequences of major topics are given here, but the intention is that teachers will design their own scheme of work. This should allow their students to make connections between different parts of the syllabus and allow the topics to form a logical sequence that is intellectually satisfying to follow. Practical work is seen as integral to the syllabus, not an added extra. Schemes of work should allow opportunities for students to develop practical skills – including analytical and interpretative skills.

Exemplar Teaching Order A – set taught by two teachers

Year 12 / Lower Sixth			
Taught by Teacher A	**Teaching time / weeks**	**Taught by Teacher B**	**Teaching time / weeks**
Term 1 (September–December)			
1.1 Eukaryotic cell structure	5	2.1 The origins of life	2
1.2 Prokaryotic cell structure	3	2.2 The chemicals of life	7
1.3 Cell replication	4	2.3 The evolution of life	3
Term 2 (January–March)			
1.6 Genes and protein synthesis	7	1.4 Enzymes	6
1.7 Applications of cell biology	5	1.5 Respiration	3
		2.4 Classification	3
Term 3 (April–July)			
3.1 Transport systems: Animals	5	4.1 Transport in plants	5
3.2 Nutrition: Animals	5	4.2 Photosynthesis	5
Revision/mock	1–2	Revision/mock	1–2
Total Y12	**36**	**Total Y12**	**36**
Revision and interim examinations: Papers 1, 2 (Part A material) and 3			

Comments

- The length of the first year has been set as 36 weeks (6 weeks per half-term on average), but this could of course vary considerably.
- Based on two teachers sharing equal teaching allocations. Some overlap will occur with term length and actual teaching progress.
- Section 1 is longer than Section 2 and so has been split between two teachers – 2.2 Chemicals of life leading into 1.4 Enzymes.
- It is assumed that a significant proportion of the syllabus content will be covered through independent learning – either as homework assignments or as longer term projects.

Year 13 / Upper Sixth			
Taught by Teacher A	**Teaching time / weeks**	**Taught by Teacher B**	**Teaching time / weeks**
Term 4 (September–December)			
3.3 Nerves, muscles and behaviour	6	4.3 Reproduction in plants	6
3.4 Homeostasis and cell signalling	6	4.4 Control of plant processes	5
Mock examinations 2 weeks			
Term 5 (January–March)			
3.5 The immune system	6	5.1 Adaptations	5
3.6 Reproduction: Animals	6	5.2 Measuring and conserving biodiversity	8
Term 6 (April–July)			
Revision and examination preparation	(6)	Revision and examination preparation	(6)
Total Y13	**24**	**Total Y13**	**24**

Comments

- The second year has been set as 24 weeks (six weeks per half-term), with time allowed for revision and consolidation.
- Mock examinations can be done as appropriate.

Exemplar Teaching Order B – set taught by one teacher

Year 12 / Lower Sixth		
Time / weeks	**Sequence**	**Outline of Content**
Term 1 (September–December)		
1	1	2.1 The origins of life
4	2	2.2 The chemicals of life
2	3	2.3 The evolution of life
2	4	2.4 Classification
3	5	1.1 Eukaryotic cell structure
Term 2 (January–March)		
2	6	1.2 Prokaryotic cells
2	7	1.3 Cell replication
5	8	1.4 Enzymes
3	9	1.5 Respiration
Term 3 (April–July)		
4	10	1.6 Genes and protein synthesis
3	11	1.7 Applications of cell biology
3	12	3.1 Transport systems in animals
2	13	3.2 Nutrition in animals
		Revision + interim examination + feedback
36 weeks total for Year 12		

Year 13 / Upper Sixth		
Time / weeks	**Sequence**	**Outline of Content**
Term 4 (September–December)		
3	14	3.3 Nerves, muscles and behaviour
3	15	3.4 Homeostasis and cell signalling
2	16	3.5 The immune system in animals
2	17	3.6 Reproduction in animals
2	18	4.1 Transport in plants
Term 5 (January–March)		
2	19	4.2 Photosynthesis
2	20	4.3 Reproduction in plants
2	21	4.4 Control of plant processes
2	22	5.1 Adaptation
4	23	5.2 Measuring and conserving biodiversity
Term 6 (April–July)		
(6)		Trial / practice / mock papers, feedback and revision
24 weeks total for Year 13		
Mock / School examinations as appropriate in year 12 and year 13.		

Exemplars **A** and **B** follow a traditional evolutionary and systems approach to Biology. Exemplar **C** takes a different path beginning with a study of organisms in their environments. This allows opportunities to do fieldwork early in the autumn term when conditions are usually suitable for the practical activities required by the syllabus. It then follows a different evolutionary and systems approach.

There is no requirement to teach topics within the section in which they appear in the syllabus. Many other paths through the syllabus are possible, often by adopting a 'context' approach to the syllabus with case studies. A 'problem-based' learning approach is also appropriate based around the questions asked at the beginning of each section of the syllabus.

Exemplar Teaching Order C – set taught by one teacher

Year 12 / Lower Sixth		
Time / weeks	**Sequence**	**Outline of Content**
Term 1 (September–December)		
2	1	5.1 Adaptation and classification from 2.4
4	2	5.2 Measuring and conserving diversity
2	3	1.2 Prokaryotic cells together with 2.4 (g)
3	4	1.1 Eukaryotic cell structure
Term 2 (January–March)		
4	5	2.2 Chemicals of life
5	6	1.4 Enzymes
2	7	1.3 Cell replication
4	8	1.6 Genes and protein synthesis
Term 3 (April–July)		
1	9	2,1 The origins of life
2	10	2.3 The evolution of life
3	11	1.7 Applications of cell biology
2	12	3.6 Reproduction in animals
2	13	4.3 Reproduction in plants
		Revision + interim examination + feedback
36 weeks total for Year 12		

Year 13 / Upper Sixth		
Time / weeks	**Sequence**	**Outline of Content**
Term 4 (September–December)		
2	14	4.2 Photosynthesis
2	15	4.1 Transport in plants
2	16	3.2 Nutrition in animals
3	17	3.1 Transport systems in animals
3	18	1.5 Respiration
Term 5 (January–March)		
2	19	3.5 The immune system in animals
3	20	3.4 Homeostasis and cell signalling
3	21	3.3 Nerves, muscles and behaviour
2	22	4.4 Control of plant processes
Term 6 (April–July)		
6		Trial / practice / mock papers, feedback and revision
24 weeks total for Year 13		
Mock / School examinations as appropriate in year 12 and year 13.		

Notes on the Curriculum Content

The syllabus is divided into five sections, as follows:

Section 1 The Cell
- 1.1 Eukaryotic cell structure
- 1.2 Prokaryotic cell structure
- 1.3 Cell replication
- 1.4 Enzymes
- 1.5 Respiration
- 1.6 Genes and protein synthesis
- 1.7 Applications of cell biology

Section 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

Section 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

Section 4 The Life of Plants
- 4.1 Transport in plants
- 4.2 Photosynthesis
- 4.3 Reproduction
- 4.4 Control of plant processes

Section 5 Environmental Studies
- 5.1 Adaptation
- 5.2 Measuring and conserving biodiversity

1. THE CELL

These questions may be put to candidates to stimulate discussion and prompt and direct their own research while covering Section 1.

- What makes eukaryotes different from prokaryotes?
- Are eukaryotes more successful than prokaryotes?
- What are the advantages and disadvantages of using electron microscopes?
- How can I determine what is inside a cell and what the parts do?
- How are intracellular structures adapted to their functions?
- How do cells replicate?
- How are meiosis and genetics connected?
- How and why do a variety of proteins catalyse such a variety of different reactions so specifically?
- If enzymes denature at 55 °C, how do organisms live in hydrothermal vents deep in the ocean or in hot springs at 95 °C?
- What is it about ATP that makes it so important?
- How is ATP made?
- Why is anaerobic respiration so much less efficient at releasing energy from a glucose molecule than aerobic respiration?
- What is the role of DNA?
- How do organisms control their genes?
- What is genetic engineering and is it a good thing or a bad thing?
- How is knowledge and understanding of Biology applied to gene technology?
- Selective breeding ..... is it genetic engineering or not?
- How do I transfer a gene from one species to another and how can I tell if I have done it successfully?

1.1 Eukaryotic cell structure

Content

Microscopy
Cell membranes
Organelles: structure and function

Useful search terms
light microscopy; electron microscopy; resolution magnification; cell membranes; fluid mosaic model; membrane permeability; membrane fluidity; transport across cell membranes; individual names of methods of transport and organelles

1.1 Eukaryotic cell structure	Notes
(a) explain the relative advantages of light and electron microscopes (including the theoretical basis for these relative advantages) (b) explain and distinguish between resolution and magnification with reference to light microscopy and electron microscopy	Students should have a basic understanding of the way in which light, transmission and scanning electron microscopes form an image. This should include the arrangement of lens and specimen, and how light or electrons are focused to form an image. This will then lead on to the properties of light and electrons and the advantages or disadvantages of each technique. The importance of sectioning and staining techniques should be noted, but details of different stains are not required. Examples of light and electron micrographs could be used and linked to the structure of the cell. The impact on biology of the discovery of both types of microscope could be discussed.
(c) discuss the importance of cell surface membranes in defining cells, as a characteristic of all living things and the extent to which they appear to be essential for life (d) describe and explain the fluid mosaic model (e) discuss the roles of membrane proteins including transporters (channels and carriers (including CFTR)), pumps, receptors and antigens	The structure and functions of the cell surface membrane should be described and its importance in defining the cell should be discussed – both in terms of the physical boundary of the cell and the interface with the surrounding environment. Structure should include reference to the phospholipid bilayer, cholesterol, membrane-bound and surface proteins, glycoproteins, glycolipids and the glycocalyx. Functions of the membrane should relate to this fluid mosaic structure. Knowledge of CFTR is essential for 1.7 (h) where use of gene therapy for cystic fibrosis is considered.

1.1 Eukaryotic cell structure	Notes
(f) describe the factors affecting the permeability and fluidity of membranes	Permeability of membranes should relate to molecular properties such as lipid solubility and molecular size, as well as the presence and type of trans-membrane proteins. Fluidity of membranes should focus on effects of temperature, degree of saturation of fatty acids and effect of cholesterol.
(g) explain how and why different substances move across membranes (including simple and facilitated diffusion, osmosis, active transport, endocytosis (phagocytosis and pinocytosis) exocytosis,(secretory pathway)	Simple and facilitated diffusion and the factors affecting diffusion should be described. Examples might include the diffusion of oxygen, carbon dioxide, glucose or amino acids. Students should be able to define osmosis in terms of water potential, solute potential and pressure potential, and be familiar with the terms turgidity, plasmolysis, isotonic, hypotonic and hypertonic. Active transport should relate to membrane proteins. Examples might include sodium/potassium or sucrose pumps. Endocytosis should be limited to a brief description of the process and its function in cells. Examples: phagocytosis in neutrophils; pinocytosis in neurotransmitter uptake. Exocytosis should relate to cell processes such as Golgi function and neurotransmitter release; the role of calcium should be included.
(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	Students should have a good level of understanding of the organelles listed, being able to recognise these from drawings or micrographs where appropriate and describe their function in cells. The highly conserved nature of proteasomes should be mentioned together with their importance in the degradation of endogenous proteins and link with protein synthesis. The link with ubiquitin should be made here. Molecular structure of proteasomes is not required.

1.1 Eukaryotic cell structure	Notes
Extension	• the varied methods used to visualise organelles; examples are dark-ground, phase contrast, oil immersion, confocal and Scanning Tunnelling Microscopy • the importance of internal membranes in compartmentalising the eukaryotic cell • differences between the organelles of different eukaryotes • the implications, advantages and disadvantages of possession of a cell wall
Practical	
(i) use a light microscope, stage micrometer scale and eyepiece graticule (ii) correctly measure, using a light microscope and specimens, the size of objects and calculate their magnification	Students should routinely use light microscopes in their studies of many sections within the syllabus. By the end of the course they should be thoroughly familiar with the light microscope and be able to calibrate an eyepiece graticule and use it to measure different specimens. They should also be able to determine the uncertainty of their measurements. There are numerous practical investigations in which these skills can be practised and assessed. The BioScope (see Appendix 2) can be used to introduce calibration of the eyepiece and its use in measuring.
(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	Students should be given opportunities to make observations using the light microscope – including making drawings, cell counts, etc. The whole organisms could be protists and the sections of small organisms could be small plants or animals. The parts of an organism are likely to be the plant and animal histology in Sections 3 and 4. Drawings should be large and un-shaded. Students should use fine, clear, unbroken lines and show clear outlines of structures. Annotations should be clear and, unless otherwise directed, refer to direct observations and not to knowledge of structure or function. Drawings should also be made from electron micrographs, which may be purchased from suppliers or downloaded from the internet.
(v) recognise organelles in a variety of cells from across the four eukaryotic kingdoms	Students should see good live specimens, photomicrographs and electron micrographs of cells from fungi, protists, plants and animals. Elodea and stamen hair cells of Tradescantia show cytoplasmic streaming particularly effectively in live cells.
(vi) investigate the movement of materials through cell membranes, for example by diffusion, osmosis and active transport	Small protists, yeasts and plant tissues can be used to investigate movement across membranes by diffusion, osmosis and active transport. The uptake of neutral red by yeasts is an example of active uptake.

1.1 Eukaryotic cell structure	Notes
(vii) estimate the water potential of a plant tissue by investigating the change in length or mass of suitable plant tissue	A typical A Level investigation using suitable plant storage tissue from fruits, roots or tubers would be appropriate. Such an investigation gives opportunities for collecting class data with spreadsheets and using them for descriptive statistics and, possibly, for carrying out statistical tests. Water potential terminology should be used throughout.
(viii) estimate the solute potential of plant cells using percentage plasmolysis of suitable plant epidermal cells	Onion, rhubarb or Rhoeo (boat lily) epidermis makes suitable material for using the limiting plasmolysis method to estimate the solute potential.
(ix) investigate the effect of temperature and different solvents on the permeability of membranes	Leakage of betalain from beetroot tissue is good material for investigating the effects of temperature and different solvents, such as ethanol, 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	Cultures of motile or sessile ciliates, such as Paramecium and Vorticella, make good material to observe endocytosis and intracellular digestion especially if fed yeasts stained with Congo red or neutral red (see (vi) above).

1.2 Prokaryotic cell structure

Content

Structure of prokaryotic cells
Pathogenic bacteria
Antibiotics
Reproduction

Useful search terms
prokaryotic structure; prokaryotic cell wall; prokaryotic ribosomes; penicillin mechanism; penicillin virus; bacterial fission; Helicobacter pylori

1.2 Prokaryotic cells	Notes
(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 and functions of bacterial ribosomes and cell walls and the significance of the structure of bacterial cell walls for the use of antibiotics (c) explain the mode of action of penicillin on bacteria (as an example of an antibiotic) and explain why penicillin does not affect viruses	Students should feel confident in being able to label a diagram of a prokaryotic cell, and be able to make comparisons with eukaryotic cells. Ribosome structure should mention RNA-protein subunits and introduce Svedberg units. The bacterial cell wall should be described and include Gram positive and Gram negative structures. This could then relate to a brief description of the mechanism of action of penicillin by binding to transpeptidases.
(d) explain the mode of transmission and infection of bacterial pathogens (including Agrobacterium tumefaciens (Rhizobium radiobacter), Clostridium tetani, Mycobacterium tuberculosis and Helicobacter pylori)	The mode of transmission for the examples given should cover basic details of methods of bacterial transmission together with brief descriptions of the immediate effects of bacterial infection (for example air-borne transmission of TB or gastric ulcers and stomach cancer resulting from H. pylori). For Agrobacterium this could include reference to its use in genetic modification.
(e) outline the mechanism of asexual reproduction by binary fission in a typical prokaryote	Brief description only required, but students should appreciate the importance of asexual strategies in survival and the spread of disease.
Extension	• discovery of H. pylori. • the metabolic and nutritional diversity of prokaryotes • the ways in which prokaryotes function without membrane-bound organelles • mechanisms of antibiotic resistance • the differences between Archaea and Eubacteria

1.2 Prokaryotic cells	Notes
Practical	
(i) investigate Gram staining of bacterial cell walls	Students should stain Gram+ and Gram- bacteria to observe the differences. They should understand the different aspects of the Gram staining procedure and explain its use in identification.
(ii) investigate the effect of penicillin or other antibiotics on bacterial growth (e.g. by use of Mast Rings)	This investigation gives the opportunity for students to practise aspects of sterile technique. Students could either investigate the effect of different concentrations of penicillin using filter paper discs or the effects of different antibiotics (using Mast Rings) on the growth of bacteria such as Bacillus subtilis (Gram+), Micrococcus luteus (Gram+) and Escherichia coli (Gram-).

1.3 Cell replication

Content

DNA replication
Mitosis
Meiosis

Useful search terms
semiconservative replication; Meselson Stahl; DNA replication models; cell cycle; mitosis; mitosis control; cell cycle control; telomeres; telomerase; telomerase reverse transcriptase; meiosis; independent assortment; crossing over meiosis; meiosis genetic variation

1.3 Cell replication	Notes
(a) outline the semi-conservative replication of DNA (b) describe the contribution of Meselson and Stahl in revealing, from various hypotheses, which model correctly describes DNA replication	Description of DNA replication (prokaryote) including mention of the replication fork, DNA polymerase I and III, RNA primers, helicase, ligase and Okazaki fragments. The results from Meselson and Stahl's experiment should be discussed in terms of models of DNA replication.
(c) outline the cell cycle including growth, DNA replication, mitosis and cytokinesis (d) describe and explain mitosis, with the aid of diagrams, in terms of chromosome, nuclear envelope and centriole behaviour with emphasis on the features of chromosome behaviour that contribute to the production of cells that are genetically identical to each other and to their predecessor	This should include a description of the events occurring in each stage and the changes in quantities of DNA and cell volume. Students should be able to identify photomicrographs of cells from prophase, metaphase, anaphase, telophase and interphase. Events during G1, S and G2 should be understood. Students should also be aware of 'checkpoints' in the cell cycle and their importance in the regulation of cell division.
(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)	Discussion of telomeres should be limited to two areas: the importance of telomere length in cell longevity (ageing) and the possible links between telomere length and cancer (and hence the importance of telomerase reverse transcriptase).

1.3 Cell replication	Notes
(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)	The behaviour of chromosomes during prophase, metaphase, anaphase and telophase of meiosis I and II should be understood and identified from photomicrographs. Reference should be made to bivalents, chiasmata and crossing over.
Extension	• the relationship of the cell cycle to apoptosis • the role of the cytoskeleton in the cell cycle • how the many long linear DNA molecules in a eukaryotic nucleus manage to replicate and separate without getting tangled up • the significance of behaviour of chromosomes during prophase I of meiosis
Practical	
(i) sequence images of eukaryotic cells undergoing mitosis	Students should view prepared and temporary preparations of tissues showing mitosis as well as suitable photomicrographs. They should be able to sequence images of cells at different stages of the mitotic cell cycle.
(ii) prepare and view slides of root tip squashes or other material showing mitosis	Temporary preparations showing mitotic figures can be made from roots tips of Allium spp. and Vicia faba. Students may use aceto-orcein, but toluidine blue is also highly recommended. The web site Practical Biology has a suitable protocol (adapted from Student Sheet 17 from SAPS).
(iii) investigate meiosis using prepared slides and photomicrographs of plant or animal tissues	There is no requirement to make temporary preparations of meiotic figures from animal or plant material, such as locust testes or pollen sacs of suitable species, but students interested in histology could be encouraged to do this as an extra activity. All students should view suitable prepared slides of meiosis, such as pollen grain and embryo sac formation in Lilium.

1.4 Enzymes

Content

Structure and function of enzymes
Enzyme kinetics
Commercial uses of enzymes

Useful search terms
enzymes; enzyme structure function; enzyme specificity; enzyme induced fit; functions of enzymes; factors affecting enzymes; factors effecting rate enzymes; activation energy; allosteric control or regulation or modulation; phosphofructokinase; phosphofructokinase and ATP; enzyme immobilisation; enzyme biotechnology; pectinase; pectinase in fruit juice production; glucose oxidase reaction; glucose biosensor; glucose biosensor principle

1.4 Enzymes	Notes
(a) explain why enzymes are essential to life	The various roles of enzymes in metabolism should be considered. This would link with other areas of the syllabus such as the role of enzymes in protein synthesis, DNA replication, digestion and respiration. It is expected that students are familiar with a wide range of enzymes from different classes including: polymerases, ligases, oxidoreductases, hydrolases and transferases.

1.4 Enzymes	Notes
(b) describe the structure and properties of enzymes (to include their role as catalysts in catabolic and anabolic reactions [both intracellular and extracellular] and the roles of intracellular kinase enzymes) (c) explain the specificity of enzymes and the induced-fit mode of action	Students should be able to describe the role of enzymes in terms of activation energy and the equilibrium of reactions. The terms exergonic and endergonic should be understood. The role of kinases should be limited to a brief explanation of their phosphorylation of other molecules and their important regulatory function inside cells. Students should also be able to describe the features of active sites 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 Vmax	Factors affecting enzymes should be related to the structure of enzymes, bonding and enzyme mechanics (formation of enzyme-substrate complex at an active site). Vmax should be understood but knowledge of Km is not required.
(e) describe end product inhibition and allosteric regulation (including phosphofructokinase and ATP)	Here, details of glycolysis should include fructose-6-phosphate to fructose-1,6-bisphosphate so that the importance of phosphofructokinase inhibition by ATP as a rate-limiting step can be emphasised.
(f) explain the impact of deficiency of phenylalanine hydroxylase (PAH) in phenylketonuria (PKU) as an example of an inherited error of metabolism	Students should understand that PKU results from a build-up of phenylalanine caused by a mutation in the PAH gene and the deficiency of this enzyme. PKU could be used as an example of a human mutation and also as an example of the effect of mutations on metabolic pathways (see 1.6).
(g) describe and explain the effect of competitive and non-competitive inhibitors on enzyme activity	Students should be able to distinguish competitive and non-competitive inhibition when presented with a suitable graph. An example of competitive inhibition could include malonate as an inhibitor of succinate dehydrogenase. Cyanide could be used as an example of a non-competitive inhibitor of cytochrome oxidase.
(h) outline the use of reverse transcriptase inhibitors and protease inhibitors for treatment of HIV infection	This should be covered when students have a knowledge of reverse transcription and the activity of retroviruses in HIV infection. A description of the two types of reverse transcription inhibitor (competitive and non-competitive) should be covered briefly. The specific details of the action of protease inhibitors are not required.

1.4 Enzymes	Notes
(i) explain the advantages of enzyme immobilisation	Limited to economic benefits (greater efficiency, reuse) and thermal stability. Different methods of immobilisation should be mentioned, to include: • cross-linking (e.g. covalent bonding to cellulose) • adsorption (e.g. silica gel) • entrapment (e.g. alginate beads).
(j) explain the commercial applications of enzymes including the use of pectinase in the drinks industry (k) explain the principles of operation of dip sticks containing glucose oxidase enzymes, and biosensors that can be used for quantitative measurement of glucose	A description of pectinase should cover its use in increasing fruit juice yield and clarification of juices and wines. Glucose oxidase converts glucose + oxygen into acid and H_2O_2. The depletion of oxygen can be used in biosensors via a transducer. H_2O_2 production causes colour changes that can be used in dipsticks. Other commercially important uses of enzymes could be mentioned but details are not required: brewing, baking, detergents, food production, dairy industry.
Extension	• Michaelis–Menten kinetics • the interrelationship between genes, enzymes and phenotype • multistep multi-enzyme pathways • means used to ensure enhanced thermostability of enzymes for high temperature applications • how interactions in the active site lower the activation energy • discuss the classification of enzyme inhibitors • enzymes in commerce and medicine
Practical	
(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	Students should carry out a range of experiments on suitable extracellular and intracellular enzymes to investigate the practical procedures appropriate for these factors. The factors could be divided between the students in a group who carry out individual or group investigations and report to all the members of the class. Enzymes supplied by the NCBE would make good source material. The inhibition of β-galactosidase can be investigated with galactose (competitive) and iodine (non-competitive) using ONPG (see Section 1.7) SAPS Scotland has a suitable protocol. Search the SAPS web site to find the instructions.

1.4 Enzymes	Notes
(ii) investigate the effect of immobilisation of enzymes on re-use of enzymes, ease of removal of enzyme from product and thermostability of enzymes	Immobilisation of suitable enzymes can be carried out using sodium alginate to make alginate beads. The effect of immobilisation on enzyme activity can be investigated. Suitable enzymes are sucrase (invertase) and lactase. Immobilised glucose isomerase is suitable for investigating the thermostability of an immobilised enzyme. Immobilised glucose isomerase is available from the NCBE.
(iii) investigate the effect of pectinase on the clarification of fruit juices	The action of pectinase can be investigated by assessing its effect on volume and clarity of apple juice. Students could be set the task of determining the effectiveness of pectinase in apple juice production. The NCBE has a suitable protocol to act as a starting point for investigations.

1.5 Respiration

Content

ATP
Chemiosmosis
Glycolysis
Anaerobic respiration
Reactions within mitochondria

Useful search terms
ATP energy; chemiosmosis; electron transport system; ATP synthase; glycolysis; anaerobic respiration; link reaction; acetyl coA; Krebs cycle

1.5 Respiration	Notes
(a) explain the need to release energy to drive metabolic reactions and the role of ATP	A general overview of energy within living cells is required – linked to other areas of the syllabus such as protein synthesis, cell division and active transport. ATP should be considered in terms of its ability to move easily within cells, universal reactivity and the reversible nature of its formation.
(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	Chemiosmosis should be seen as a universal system used in both respiration and photosynthesis in prokaryotic and eukaryotic cells. Structure of ATP synthase is not required. Students could research the evidence for chemiosmosis in chloroplasts.
(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	Basic steps of glycolysis are required (as syllabus), pyruvate to acetylcoenzyme A and the main stages of the Krebs cycle (namely citrate, α-ketoglutarate and oxaloacetate).

1.5 Respiration	Notes
(e) outline anaerobic respiration in animals limited to the oxidation of reduced NAD to regenerate NAD and conversion of pyruvate to lactate and at the same level of detail, compare and contrast this with anaerobic respiration in yeast and plants (f) compare and contrast the energy released per molecule of glucose substrate in aerobic and anaerobic conditions and explain the reasons for the difference	Outline anaerobic respiration in the same depth as aerobic and compare them in terms of ATP production, products and efficiency.
Extension	• the significance of ATP being both the universal 'energy currency' and a building block of nucleic acids • the effect of end-product inhibition by ATP or respiratory toxins such as cyanide on the rate of respiration • the respiration of other respiratory substrates such as proteins and lipids • determining the respiratory quotient (RQ) and evaluating its significance
Practical	
(i) investigate the rate of glucose respiration by yeast in aerobic and anaerobic conditions	Various designs of respirometer can be made from boiling tubes, syringes and capillary tubing to investigate the rate of respiration by yeast in aerobic and anaerobic conditions. Students should consider the variables that they need to control and ways in which they can measure the rate of carbon dioxide production. It is not expected that students will have used a Barcroft respirometer with two flasks connected by a manometer, although they should be aware that such an apparatus is used to determine respiration rates. Respiration could also be investigated using redox dyes, such as methylene blue and triphenyl tetrazolium chloride (TTC).
(ii) investigate the effect of temperature on the rate of respiration using simple respirometers	Investigations of the effect of temperature on respiration rate may be combined with those in (i), but may also be carried out on other material, such as germinating seeds and small insects. Mung beans, blowfly larvae and mealworms are suitable.

1.6 Genes and protein synthesis

Content

- The gene and genetic code
- Protein synthesis
- Control of gene expression
- Inheritance and Mendelian inheritance
- Mutations
- Genetic conditions

Useful search terms
gene and allele or locus; genetic code; transcription; DNA translation; introns DNA; introns splicing; Mendelian genetics; dihybrid cross; sex linkage; genetic linkage; genetics chi square; mutation; apoptosis; proto oncogene; tumour suppressor genes; mutation and deletion or substitution or insertion; chromosome mutation; sickle cell anaemia; sickle cell anaemia genetics ; hereditary haemochromatosis; hereditary haemochromatosis genetics; hereditary haemochromatosis HFE

1.6 Genes and protein synthesis	Notes
(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. Discuss the limitations of the latter definition with reference to introns, exons and promoters	This should introduce students to the idea that genes are not simply sections of DNA at one locus, but numerous exons separated by introns and controlled by 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	A fundamental understanding of the genetic code and protein synthesis is required. Transcription should include an explanation of a DNA coding strand and RNA polymerase to produce mRNA from free nucleotides. Amino acid activation should be explained in terms of an amino acid reacting with an enzyme complex (synthetase/transferase details not required) which then binds to a specific tRNA carrying an anticodon. Translation should refer to ribosome structure, codons and the sequence of events leading to polypeptide formation. Polysomes should also be mentioned.
(e) define the term proteomics and outline its importance to biomedicine (limited to diagnosis and drug design)	Students should be aware of the limitations of studying the genes alone (genomics). Proteins interact and therefore a study of proteins (proteomics) is important in order to understand how cells and drugs work.
(f) describe, in outline, the control of gene expression (limited to the lac operon in prokaryotes)	This should introduce the idea of an operon in prokaryotes. Students should be familiar with the terms promoter, operator, repressor protein, structural genes and terminator.
(g) state, with examples, the differences between continuous and discontinuous variation (limited to relative number of genes and alleles involved and relative impact of the environment as well as relative range of phenotypes)	Examples of variation might link with evolution in Section 2 and the adaptations described in Section 5.

1.6 Genes and protein synthesis	Notes
(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. (The formula for the chi-squared test will be provided.)	Students will be expected to be able to solve monohybrid and dihybrid genetics problems. Suggested examples: • Dihybrid/crossing over: wing/body type in Drosophila • Sex linkage: haemophilia or colour blindness in humans, eye colour in Drosophila • Autosomal linkage: flower colour and pollen shape in sweet peas, or wing/body type in Drosophila • Epistasis: mouse coat colour or snail shell banding • Codominance and multiple alleles: ABO blood groups. Before using the chi-squared test, students should be made aware of the principles of statistical tests (see Appendix 3).
(k) explain that the effects of ionising radiation on living cells can have a range of outcomes including DNA damage which is repaired, DNA damage that cannot be repaired, leading to apoptosis, and DNA damage causing mutations. Mutations that do not kill the cell but are passed on to its descendants during cell division (including mutations that can cause cancer, e.g. those that cause proto-oncogenes to become oncogenes and those that reduce the activity of tumour-suppressor genes)	Exact details of DNA repair mechanisms are not required but some reference to cell cycle checkpoints could be used to refer to 1.3(d) Students would be expected to understand the role of proto-oncogenes, oncogenes and tumour-supressor genes.

1.6 Genes and protein synthesis	Notes
(l) describe gene mutations, limited to substitution, deletion and insertion (m) explain, with reference to sickle cell anaemia, cystic fibrosis and hereditary haemochromatosis, how gene mutations might affect expression of a protein and thus affect phenotype (issues related to genetic conditions need to be handled with sensitivity) (n) describe the causes and outline the symptoms of hereditary haemochromatosis (HH) as an example of a recessive genetic condition (reference should be made to HFE protein)	Detail about each condition should include: • sickle cell anaemia: Haemoglobin gene and production of Haemoglobin-S • cystic fibrosis: CFTR gene with reference to trans-membrane protein pumps • hereditary haemochromatosis: HFE protein and iron transport.
Extension	• possible reasons for the existence of introns • methods used to produce chromosomal maps • the genetics and impact of other genetic conditions which might include autosomal recessive or dominant conditions, sex linked conditions, mitochondrial conditions, polygenic conditions or conditions caused by chromosomal mutations • pleiotropic effects of sickle cell mutation in the gene for β globin • the roles of genetic screening for genetic conditions • the role of genetic counsellors • the impact of histone proteins on packaging and control of eukaryotic genes • silent mutations

1.6 Genes and protein synthesis	Notes
Practical	
(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	Long-term studies of genetics are often difficult to coordinate with the teaching of the relevant topics. If started at the time of teaching, the final results are not usually available until many months later. This is less of a problem with Pre-U than it is with modular A levels. However, it is possible to 'dovetail' the generations by planning ahead and setting up parental and F_1 crosses at the same time. This means that F_1 and F_2 generations are available together. This is possible with cultures of Drosophila for example and with seeds of maize. There is no substitute for carrying out genetics investigations although simulations allow the investigation of many more types of crosses. If suitable conditions are available to grow rapid-cycling Brassica ('fast plants') then these should be used to match a variety of learning outcomes in the syllabus (see Section 1 and Section 5) as well as this one. Sordaria fimicola may be used to demonstrate and investigate crossing over.
(ii) investigate continuous and discontinuous variation with any available materials (e.g. people, plants with suitable single-gene and polygenic characteristics, polymorphic snails, etc.)	Data on continuous and discontinuous variation may be collected and analysed statistically using spreadsheets. Collection of data on people, particularly students, should be handled sensitively as many single-gene traits are discussed in text books and web sites in very simplistic terms that are often incorrect or misleading. Examples are tongue rolling and eye colour. Cepeae nemoralis or Cepaea hortensis may be collected locally and features such as banding and background colour may be investigated and compared with secondary data.

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 using stem cells

Useful search terms
genetic engineering; gene manipulation; reverse transcriptase; reverse transcriptase cDNA; restriction enzyme; gene probe; polymerase chain reaction; taq polymerase pcr; plasmid vector; Agrobacterium; microprojectiles; plasmid resistance gene transformed; plasmid fluorescent gene; transformation; gene therapy; gene therapy cystic fibrosis; gene therapy SCID; genetic profiling; genetic fingerprinting; gene sequencing; DNA sequencing; sequencing chain termination; sequencing dye terminator; human genome; human genome size

1.7 Application of cell biology	Notes
(a) discuss the potential and actual advantages and disadvantages of transferring genetic material by genetic engineering compared to selective breeding	Advantages would include a variety of environmental, economic and medical benefits. Disadvantages might include the potential health and environmental risks and unforeseen consequences of any new technology. Safeguards such as regulatory procedures and government guidelines should be discussed and moral issues raised. This could be covered as part of Section 1.7(m)
(b) explain why promoters and other control sequences may have to be transferred as well as the desired gene	This should relate to the regulation of transcription.

1.7 Application of cell biology	Notes
(c) 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 (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 and then inserting the plasmid vector into a host cell • use of Agrobacterium tumefaciens in inserting DNA into dicotyledonous plant cells • use of microprojectiles in inserting DNA into monocotyledonous plant cells (e.g. in creating Golden Rice™ and Golden Rice 2) (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.	Students are expected to have a good level of understanding of these procedures. In addition, students should be aware of the use of plasmids as vectors for gene transfer and the ways in which gene probes function. The origins of reverse transcriptase and restriction enzymes could be mentioned. Methods for selecting transformed organisms should also be discussed.

1.7 Application of cell biology	Notes
(f) outline the principles of PCR as used to clone and amplify DNA and discuss the source and importance of Taq polymerase	Students should be able to recognise the importance of having a heat stable enzyme and be aware of thermophilic bacteria.
(g) outline how genes are inserted into target cells in gene therapy (limited to liposomes and viral vectors) (h) explain the limitations, both potential and actual, of gene therapy as a treatment for genetic conditions (including cystic fibrosis and severe combined immunodeficiency [SCID])	Gene therapy using liposomes, retroviruses and adenoviruses should be considered. A basic understanding of SCID is required (defective T-cell production) but the specific nature of the faulty genes is not needed. An understanding of the causes and symptoms of cystic fibrosis is expected and students should be aware of the CFTR gene.
(i) outline the processes used in genetic profiling (DNA fingerprinting) including the use of restriction endonucleases, amplification, electrophoresis visualisation (e.g. by fluorescently tagged primers) and match tables	Students should be able to describe the technique of genetic profiling with reference to: • the use of restriction enzymes • amplification by use of PCR • the importance of Short Tandem Repeats (STR) • the use of gel electrophoresis • using fluorescent markers to tag DNA primers. Students should be able to analyse a simple genetic profile obtained by DNA fingerprinting.
(j) 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)	A simple description of both chain termination and dye-termination methods is required. Students should be able to determine the base sequence for a short section of DNA from data collected by both sequencing techniques. Students should understand the importance of advances in sequencing methods on the completion of the Human Genome Project. Reference to taxonomic uses should relate to Section 2.4(a). Clinical diagnosis might include the importance of DNA sequencing in control of the spread of diseases such as avian influenza or typhoid.

1.7 Application of cell biology	Notes
(k) describe how stem cells (zygotic, embryonic and adult) are obtained for research (l) discuss the current and potential uses of stem cells (e.g. replace damaged tissues, study aspects of development and cell chemistry, test new drugs, screen potentially toxic chemicals, facilitate gene therapy)	Students should be aware of the different sources of stem cells: • Zygotic: from the fusion of an egg and sperm cell or within a few divisions of the zygote • Embryonic: obtained from cells of the blastocyst inner cell mass • Adult: somatic cells obtained from body tissues such as blood or bone marrow. The advantages or disadvantages of these types of stem cells could also be discussed (as covered in Section 1.7(m)) Uses of stem cells might include: • Replacement of damaged body tissues: Parkinson's disease, leukaemia or multiple sclerosis • Developmental and cell biology: how studies of the characteristics of stem cells have allowed us to discover more about cancer cells and how cells develop and differentiate in an embryo • Drug and toxicity testing: students should appreciate the importance and benefits of using stem cells as a tool for testing chemicals and new drugs • Gene therapy: students should be able to relate the properties of stem cells with their potential use in gene therapy (this should be linked to Section 1.7(g) and (h)).
(m) discuss the ethical implications of the applications of genetic engineering and stem cells, including agricultural, industrial, research and medical applications	Students might consider: • Agricultural: the genetic engineering of food crops with examples that could include herbicide resistance • Industrial: the use of genetically engineered enzymes for food production • Research/medical: the methods of obtaining stem cells and subsequent use in medical research and clinical treatment.

1.7 Application of cell biology	Notes
Extension	• the ways in which promoter sequences are used to enable genes from one Kingdom to function in organisms of another • bacteriophages as vectors • varied examples of genetic engineering to find out how identification, isolation, cloning and transfer of the desired genes and promoters were achieved • the control and differentiation of stem cells (including gene expression and production of a range of cell types) • categories, nomenclature, plasticity and potency of stem cells • why gene therapy has been so slow to take off • use of genetic profiling in studying inheritance of and testing for genetic conditions • capillary electrophoresis • DNA databases • other methods for visualisation of DNA • induced pluripotent stem cells • animal testing
Practical	
(i) investigate aspects of genetic profiling including practical investigation of electrophoresis using dyes and DNA fragments	Students should have experience of carrying out electrophoresis. This is best started with separation of proteins or dyes. Separation of DNA fragments can be done in the context of restriction mapping and/or simple forensic simulations. Suitable kits are available from suppliers, such as the NCBE, Bio-Rad and Edvotek (see Appendix 4).
(ii) investigate transformation of bacteria, e.g. using the pGLO plasmid	Kits for this investigation are available from suppliers, such as Bio-Rad and the NCBE.
(iii) investigate the lac operon using ONPG solution	Protocols for this are available on the SAPS, NCBE and Practical biology web sites. See Appendix 2 for details of web addresses.

Opportunities for independent learning:
It is expected that students should carry out independent learning including; posters, booklets, audiovisual presentations, summarising an aspect of a topic or other means of communicating information. This could be made available to the group and others who are interested, as part of a group display using wall space or audiovisual media as appropriate, or as a synoptic revision exercise.

the Human Genome Project;
protein synthesis;
the mitotic cell cycle;
uses of stem cells;
ATP;
electron transport systems;
biochemistry of respiration;
aspects of respiration of varied substrates;
aspects of Mendelian genetics;
the use of statistics in genetics;
variation;
applications of microbes or enzymes;
immobilisation;
glucose monitoring;
antibiotics;
aspects of ethics in biotechnology;
DNA profiling;
aspects of the biology of genetic conditions;
genetics in the health services;
aspects of genetic engineering;
promoters;
PCR;
vectors and insertion of DNA into host cells;
identification of successfully transformed cells

2. THE ORIGIN AND EVOLUTION OF LIFE

These questions may be put to candidates to stimulate discussion and prompt and direct their own researches while covering Section 2.

- How and why did life get started?
- Why are we so sure about the 'historical fact of evolution' and why are some people not so sure?
- Why is water essential for life?
- Where would life be without proteins?
- How independent are mitochondria and chloroplasts?
- What are the mechanisms that drive evolutionary change?
- What is the evidence that evolution explains life in all its richness?
- Why have some organisms become multicellular?
- What exactly defines a species?
- Why is Charles Darwin a controversial figure for some?
- What are the benefits of the classification of organisms?

2.1 The origins of life

Content

Origin of complex organic molecules
Origin of prokaryotic and eukaryotic cells
Advantages of multicellularity

Useful search terms
Miller-Urey; origin of life; biochemical origin of life; endosymbiosis; origin of eukaryotes; multicellular; multicellular advantages

2.1 The Origins of life	Notes
(a) outline the Miller-Urey experiment that showed that complex organic molecules (including amino acids) can form from simple inorganic molecules when subjected to the conditions once thought to have prevailed on Earth 4 billion years ago when life is thought to have originated	Students should understand the rationale behind the Miller-Urey experiment (i.e. what was included in the experiment) and what the results showed, but details of the chemistry involved are not required.
(b) 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	This section could call on the students' knowledge of the universality of the genetic code and introduce them to the idea of proteins changing over time – with some such as ubiquitin remaining almost unchanged in all forms of life. The role of ubiquitin as a marker for proteins targeted for destruction should be described. Proteasomes should have been covered in Section 1.1.
(c) 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	Evidence for endosymbiosis should refer to mitochondria and chloroplasts and include: double membranes, DNA, ribosome type, type of reproduction, size, similarities in biochemistry/enzymes (details not required).
(d) discuss the advantages and disadvantages of being multicellular (limited to division of labour and specialisation, greater control of the internal environment, as against, increased complexity and coordination issues, vulnerability to trauma)	Students should be able to discuss issues associated with becoming multicellular, referring to: • Division of labour: specific examples could be included here such as specialised cells involved in the digestive system (Section 3.2) or the immune system (Section 3.5) • Greater control of the internal environment: with reference to Section 3.4 • Coordination issues: the need for a nervous system (Section 3.3) or communication system (Section 4.4) • Vulnerability to trauma: dependence on other cells leads to vulnerability to trauma. Students should have considered multicellular organisms that are less vulnerable to trauma such as sponges.

2.1 The Origins of life	Notes
Extension	• the evidence for the dates of origin of the earth, life, eukaryotes and multicellularity • why only eukaryotes became multicellular • are biofilms multicellular? • why scientists have moved from 'metabolism first' ideas about abiogenesis to 'replication first' ideas • modern ideas about how abiogenesis occurred • why can't mitochondria/chloroplasts survive outside the cell?
Practical	
use a microscope or photomicrographs to compare small multicellular eukaryotes (e.g. Volvox, rotifers, tardigrades) with unicellular eukaryotes (e.g. Amoeba, Euglena, ciliates)	Suitable multicellular and unicellular eukaryotes may be collected from pond water, prepared from hay infusions or collected from searches of leaf litter, soil and other habitats. Students could prepare presentations on a variety of named organisms and illustrate with a collection of live specimens. The organisms listed are examples; students should be prepared to make observations about any small multicellular eukaryote and unicellular eukaryote.

2.2 The chemicals of life

Content

Water
Lipids
Carbohydrates
Proteins
Nucleic acids

Useful search terms
water properties; triglycerides; phospholipids; ester bonds; saturated unsaturated fatty acids; structure function and glucose or ribose or maltose or sucrose or starch or cellulose or glycogen; glycosidic bonds; amino acids; structure function and amino acids or globular proteins or fibrous proteins; peptide bonds; protein structure; ATP structure function; nucleotides; DNA structure; RNA structure; mRNA; tRNA; Watson Crick Franklin Wilkins; examples of scientific method

2.2 The chemicals of life	Notes
(a) describe the chemical and physical properties of water and explain the biological significance of these properties	Students should be able to link the structure of the water molecule to its properties: • latent heat of vaporisation • specific heat capacity • properties as a solvent • cohesion • density The importance of these properties should be understood in terms of living organisms.

2.2 The chemicals of life	Notes
(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	General structure of triglycerides is required together with ester bond formation. Specific structure of named fatty acids is not required. Students should be aware of the differences between unsaturated, mono-unsaturated and poly-unsaturated fatty acids. This could lead to a discussion of the relative melting points of saturated and unsaturated fatty acids. The structure of phospholipids is required for Section 1.1 and membrane structure. A brief discussion on the health issues associated with dietary fats might lead onto unit 3.1 and CHD.
(e) describe the structures and properties of monosaccharides (α- & 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	Students should be familiar with molecular and structural formulae, and be able to describe condensation and hydrolysis reactions.

2.2 The chemicals of life	Notes
(g) describe the structures and properties of amino acids; globular proteins (including enzymes and haemoglobin) and fibrous proteins (including keratin and 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)	The roles of named proteins should be taught, but students should also be aware of the importance of protein interactions (proteomics discussed in Section 1.6). The complexity of some proteins should be appreciated but detailed knowledge of prosthetic groups is not required (apart from haem).
(k) describe the structure of nucleotides to include ATP (l) describe the condensation of nucleotides to form nucleic acids (m) describe the structure of DNA and RNA (limited to mRNA and tRNA) (n) discuss the scientific method with reference to the contributions of Crick, Watson, Wilkins and Franklin in formulating and testing hypotheses in identification of DNA structure	The structure and properties of ADP and ATP should be covered as part of the knowledge required for section 1.5. Students should have a good understanding of nucleic acid structure and be able to relate this to the properties of DNA and RNA seen in replication, transcription, translation, mutation and genetic modification. Students should be aware of the story of the sequence of events that led to the discovery of DNA and the contributions made by Crick, Watson, Wilkins and Franklin.

2.2 The chemicals of life	Notes
Extension	• why water may be considered essential for life • other hypothetical chemistries of life in serious science and fiction • the diversity of carbohydrates and/or lipids and/or organic acids and/or vitamins • the formation and role of peptidoglycans in prokaryote cell wall or chitins in the cell walls of fungi and exoskeletons of insects • the importance of prosthetic groups • the impact of mutations in producing different alleles, varying the primary structure of proteins and therefore the shape of both non-essential and function-critical parts of enzymes and other globular proteins
Practical	
(i) investigate some of the key physical and chemical properties of water	Students could research practical demonstrations of the key properties listed in 2.2(a) and carry them out as presentations to the class.
(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	It should be stressed that these are **not** food tests. Students should use these common tests in the context of investigations. Perhaps by designing a key to identify the composition of a biological material; by investigating the activity of immobilised enzymes (see 1.4(i)), the hydrolysis of starch by different amylases and the effect of sucrose concentration on the activity of sucrase. They can also devise quantitative tests, using colorimetry, to find concentration of proteins and reducing sugars.
(iii) investigate the energy content of carbohydrates, lipids and proteins, using simple calorimetry	Biological materials that consist primarily of one substance can be used to investigate the energy content. Examples are sugar, cooking oil and gelatine. Students could use this simple activity as a vehicle for evaluating methods and results. Bomb calorimetry can be used if available.

2.3 The evolution of life

Content

Selection and changes in allele frequency
Speciation
Aspects of evolution

Useful search terms
Darwin Wallace evolution; adaptive radiation; Galapagos finches; Galapagos mockingbirds; microevolution; evolutionary changes in allele frequency; natural selection; selection + directional OR disruptive or stabilising; climate change biodiversity; climate change food chain; climate change niche; extinction rate; background extinction rate; speciation + allopatric OR sympatric; ring species; cichlid evolution; antibiotic resistance

2.3 The evolution of life	Notes
(a) outline Darwin's and Wallace's observations and conclusions	These observations should include: • fecundity • variation (island biogeography could be mentioned here) • survival rates • inheritance of characteristics • population sizes. The contributions made by others could also be mentioned but details are not required (the thoughts of Malthus and Lyell for example).

2.3 The evolution of life	Notes
(b) describe evolutionary patterns of divergence and adaptive radiation including the Galápagos 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; how such variations might enable organisms with particular alleles and particular phenotypes to survive better and reproduce more frequently	Students should be able to describe the mechanisms of evolution based on genetic variation and selection in a variety of niches.
(d) describe and explain directional, stabilising and disruptive selection	The following examples could be used: • Directional: selection of beak size in Passerines (Galápagos finches) or antibiotic resistance in bacteria • Stabilising: human birth weight. Students should be aware of the idea of heterozygote advantage, with sickle cell anaemia being a possible example • Disruptive: butterfly mimics such as Pseudacraea eurytus or polymorphism in the beak of Pyrenestes ostrinus where intermediates are selected against.
(e) discuss what effect increased environmental stress resulting from global climate change (with increased temperatures and more extreme weather conditions) might have on habitats and organisms and thus on food chains and niche occupation	Global climate changes might include drought, flood, temperature and humidity changes. The impact of these on populations could include changes in tick or mosquito numbers and distribution. Students should be able to explain this in terms of selection. This obviously links closely with Sections 5.1 and 5.2.
(f) compare current and background rates of extinction with those during past mass extinctions (students should be aware that these figures are not agreed by all scientists)	Students should be familiar with at least one major extinction event (possibly the end-Permian extinction event or the K-T mass extinction) and compare this with current estimated extinction rates.

2.3 The evolution of life	Notes
(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)	Allopatric speciation should refer to examples of geographical isolation and could include the ring species: Ensatina salamanders, Larus gulls or the warbler Phylloscopus trochiloides. Galápagos mockingbirds would be a good example of the effect of isolation. Sympatric speciation should include the rapid speciation seen in African cichlids and refer to behavioural isolation based on sexual selection and niche segregation.
(h) explain the causes and effects of bacterial genetic resistance to antibiotics	Examples of antibiotic resistance could be described such as MRSA, MDR-TB or Neisseria gonorrhoeae H041. The potential threat of these strains and concerns of the World Health Organization should be discussed.
Extension	• the founder effect and genetic drift • the neutral theory of evolution • the natural events leading to mass extinctions • the impact of antibiotic resistance on medicine • kin selection, inclusive fitness and social animals • whether it is possible to reconcile theist and evolutionary theories of the origin of species • the modern evolutionary synthesis
Practical	
investigate the relationship between aspects of the environment and features of species such as banded snails (Cepaea spp.)	Students could make collections of suitable organisms and investigate relationships between morphological and other features and environment. Adaptations can be investigated with mollusc species such as banded snails, Cepaea spp., limpets, Patella spp. and dogwhelks, Nucella lapillus and also with locally adapted populations of plants, such as marram, Ammophila arenaria and protists, such as eggwrack, Ascophyllum nodosum.

2.4 Classification

Content

The species concept;
Classification systems

Useful search terms
definition of species; species concept; phylogenetic; phenetic; classification of organisms; 5 kingdom classification; 3 domain classification; domains and kingdoms; viruses alive; mimivirus

2.4 Classification	Notes
(a) define the term species with reference to morphological, genetic and biochemical similarities and capability to produce fertile offspring	Morphological: Refer to obvious similarities between members of the same species, but also to differences in morphology such as sexual dimorphism in many birds. Genetic: DNA-DNA hybridisation should be described as a method of determining species similarities. Biochemistry: Amino acid comparison in proteins and immunological comparisons should be understood. Reproduction: Including reference to sterile hybrids and suitable examples. Students should appreciate that there are different ideas about the 'species concept'.
(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	The importance of phylogenetic classification systems based on comparative molecular biology should be discussed. Students should be able to appreciate the disadvantages of the phenetic system, where morphological differences are used. Students should also understand the continued use of phenetic classification in cases where no biochemical/DNA comparisons exist.

2.4 Classification	Notes
(d) describe the hierarchy of seven major taxonomic groups from kingdom to species with reference to an example (e.g. Homo sapiens) (e) understand the term binomial nomenclature and why Latin and Greek are used for biological nomenclature	Specific examples of named organisms and their complete classification are not required. Students should be able to identify the genus and species from an organism's scientific name and be familiar with the role that Linnaeus played in the development of the binomial system of classification.
(f) discuss the merits of the five kingdom and the three domain classification systems (limited to utility and phylogenetic validity)	Five kingdoms: Characteristic features of the five kingdoms should be learnt, but the emphasis should be placed on the reasons for placing organisms into these kingdoms. This emphasises that systems of classification are human constructs used simply to help us organise and describe living things. Three domains: Differences in cell membrane lipids, enzymes and RNA (specifics not required) could be used to illustrate flaws in the five kingdom system and preference for using three domains.
(g) explain the difficulties of including viruses in classifications of organisms	Characteristic features of viruses should be learnt and their methods of transmission briefly described. The discovery of mimivirus (Acanthamoeba polyphaga mimivirus) could be used to highlight the difficulty in classifying viruses.
Extension	• how many species there are • the breadth of biodiversity • why it is difficult to define the term species • other attempts to define species • the kinds of classifications used • monophyletic, paraphyletic and polyphyletic taxa • molecular phylogenetics
Practical	
(i) recognise key features of the different kingdoms from specimens, photographs and drawings (ii) use dichotomous keys to identify organisms from different taxa	These tasks are best done in conjunction with field work. Students could list the key features of the different kingdoms and use specimens collected or photographed in the field as exemplars. Students will be expected to use dichotomous keys in the examinations, so should have experience of using them for identifying organisms they collect in the field. Field Studies Council keys are recommended.

Opportunities for independent learning:
It is expected that students should carry out independent learning including; posters, booklets, audiovisual presentations, summarising an aspect of a topic or other means of communicating information. This could be made available to the group and others who are interested, as part of a group display using wall space or audiovisual media as appropriate, or as a synoptic revision exercise.

the origin, diversity or cellular biology of eukaryotic cell or multicellular organisms;
aspects of evolutionary mechanisms;
impact of environmental change in the past or present;
speciation;
evolution of social behaviours;
the variety of classification systems.

3. ANIMAL PHYSIOLOGY

These questions may be put to candidates to stimulate discussion and prompt and direct their own researches while covering Section 3.

- Why do large organisms need a transport system?
- How do animals cope with different diets?
- What happens when we age?
- How do animals move?
- Why do we need to control internal conditions?
- Why do organ transplants face rejection, but a fetus doesn't?
- To what extent is the placenta a 'life support machine' for a fetus?

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

Useful search terms
surface area volume ratio; insect tracheal system; insect gas exchange; bony fish gills; bony fish gas exchange; gill countercurrent; mammal gas exchange; mammal respiratory system; circulatory system; open and closed circulatory system; single circulatory system; double circulatory system; amphibian circulatory system; artery vein capillary separately and together; mammalian blood and names of individual components; human heart; cardiac cycle; cardiac cycle pressure; sinoatrial node; atrioventricular node; heart and Purkyne tissue: heart depolarisation; heart electrical system; cardiac control centre; blood clotting; haemoglobin oxygen transport; haemoglobin oxygen dissociation curve; Bohr shift; carbon dioxide transport in blood

3.1 Transport systems	Notes
(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	This should include calculations of surface area to volume ratio and the impact of this on movement of digested food, wastes, oxygen and heat throughout the body. Students should be able to explain the need for transport and gas exchange systems in larger animals (referring to mass flow). The methods by which some organisms cope without complex transport/gas exchange systems could be covered in section 5.1.

3.1 Transport systems	Notes
(c) compare ventilation mechanisms and gas exchange in insects, fish and mammals	The structure and function of the gas exchange systems should be covered and include: • Insects: impermeable exoskeleton, spiracles (mentioning valves and hairs), tracheae, tracheoles and muscular ventilation • Fish: gill arches, filaments and lamellae, counter-current exchange and methods for maintaining the flow of water • Mammals: trachea, bronchi, bronchioles, alveoli, diaphragm, ribs and associated muscles. The functions of the pleural membranes should also be covered. Control mechanisms are not required.
(d) discuss the advantages and disadvantages of: • open and closed transport systems • single and double circulatory systems including the increasing complexity and efficiency of circulatory systems of fish, amphibians and mammals	Open circulatory system: • all body tissues in direct contact with the blood • no control over distribution of blood to certain tissues • relatively low oxygen levels in blood. Closed circulatory system: • blood needs to be under high pressure • blood flow can be directed and flow controlled. Single circulatory system: • e.g. fish • found in organisms with low oxygen requirements. Double circulatory system: • e.g. frog and humans • a double system allows blood to circulate at high pressure around the body tissues.

3.1 Transport systems	Notes
(e) describe the structures and functions, and explain the relationship between structure and function of: • mammalian arteries, veins and capillaries • cellular components of mammalian blood (including erythrocytes, platelets, lymphocytes, neutrophils, monocytes) • the mammalian heart – cardiac cycle including pressure changes in the heart, its electrical coordination and its control by the medulla oblongata in the brain	A good understanding of the structure and function of the cardiovascular system is required. The functions of white blood cells are covered in Section 3.5 Control by the medulla oblongata should include: • baroreceptors and chemoreceptors in the aorta and carotid • cardiovascular control centre in the medulla oblongata • sympathetic and parasympathetic innervation • effects on SAN and AVN to increase heart rate and stroke volume.
(f) outline the roles of low-density lipoprotein (LDL) and high-density lipoprotein (HDL) in metabolism and transport of lipids and in atherosclerosis (g) outline the aetiology of coronary heart disease (CHD) as an example of a cardiovascular disease (h) outline the roles of drugs (limited to warfarin and statins) and surgery (limited to valve replacements, bypass surgery, transplants and stents) in treatment of cardiovascular disease	The role of LDL and HDL in lipid metabolism and transport should be limited to the transport of cholesterol to/from the liver/body cells/atheroma (could be linked to 3.4(b)). Atheroma formation should include the role of macrophages. Students should understand: • Warfarin: its role as an anticoagulant (by reducing vitamin K) • Statins: their role in reducing LDL cholesterol • Surgery: how valve replacement, coronary bypass, transplantation and stents are used (exact technical details of procedures not required).

3.1 Transport systems	Notes
(i) explain the functions of blood limited to clotting and the transport of oxygen and carbon dioxide (j) explain the significance of oxygen haemoglobin dissociation curves and the Bohr effect	Students should be able to describe the clotting of blood limited to platelets, clotting factors, prothrombin, thrombin, fibrinogen and fibrin. The importance of vitamin K should be appreciated but details are not required. Oxygen transport should include the formation of oxyhaemoglobin and dissolved oxygen. Carbon dioxide transport should include carbaminohaemoglobin, bicarbonate ions and dissolved carbon dioxide. Students should appreciate the importance of the Bohr effect and the significance of different oxygen affinities (in low oxygen environments) and relate these to adaptation (see Section 5.1).
Extension	• the effect of shape on surface area and volume • pressure and flow rate throughout the mammalian circulatory system • the impact of the different oxygen dissociation curves of fetal haemoglobin, adult (maternal) haemoglobin and myoglobin • the energetics of material exchange and mass transport in a variety of organisms (suggestions include homeothermic, poikilothermic and sessile animals; flowering plants and giant kelps)
Practical	
(i) observe the similarities and differences between mammalian blood cells, restricted to erythrocytes, lymphocytes, neutrophils and monocytes	Students should use stained smears of mammalian blood and a good histology text or images taken from histology web sites, to identify different types of white blood cell. They should make labelled and annotated drawings. Students could make presentations of their findings illustrated with electron micrographs of the different cell types to show how the cells are adapted for their functions.
(ii) investigate the tracheal system of an insect (e.g. locust), the gills of a fish and the trachea and lungs of a mammal	Locusts and fish gills should be dissected. Both can be observed in situ and ex situ with dissecting microscopes. Temporary or permanent preparations of locust tracheae can be made. Students can take measurements of fish gills and estimate the total surface area. Students could compare the gill structure of cartilaginous fish, e.g. Scyliorhinus canicula and a bony fish, e.g. Clupea spp.
(iii) explain the relationship between structure and function of heart and blood vessels (artery, vein and capillary) using prepared slides (X-ref Section 3.4(iii))	Students should carry out a complete dissection of heart, trachea, bronchi and lungs of a mammal. These are available from butchers and abattoirs sold as plucks. Structures could be identified with flag labels and then photographed to keep a permanent record. The structure of elastic and muscular arteries can be compared with thar of veins using prepared slides and photomicrographs. Blood flow in capillaries can be observed in videos of circulation in tadpole tails. The structure of capillaries can be studied from electron micrographs.

3.2 Nutrition

Content

Modes of nutrition
Mammalian alimentary canal and digestion

Useful search terms
herbivore digestive system; carnivore digestive system; mammalian digestive system; histology and stomach or ileum or pancreas; human digestion; salivary amylase; pancreatic and amylase or enzymes or lipase or exopeptidase; maltase digestion; pepsin; trypsin; bile digestion lipid

3.2 Nutrition	Notes
(a) compare and contrast the modes of nutrition, dentition and digestive systems of herbivores and carnivores	A typical herbivore (non-ruminant) could be studied, together with a typical carnivore. Mode of nutrition: Differences in dietary composition, time spent eating and efficiency Dentition: Simple comparison of herbivore and carnivore dentition Digestive system: Length and regional specialisation
(b) recall the structure and function of the mammalian alimentary canal including histology of 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; pepsin and trypsin as endopeptidases; exopeptidases; lipase (d) explain the parts played by bile, mucus and sodium hydrogen carbonate in digestion	Students should know the function of the different regions of the mammalian digestive system and be able to relate this to the action of enzymes, bile, mucus secretion and sodium hydrogen carbonate. The digestion and absorption of carbohydrates, proteins and lipids should be covered.

3.2 Nutrition	Notes
Extension	• the contrast between the modes of nutrition of multicellular and unicellular eukaryotes as well as prokaryotes • nutrient requirements of animals • nutrition, dentition and guts of omnivores • the means used to prevent the enzyme secretory glands and the digestive system from digesting themselves • why digesting protein requires so many types of enzymes compared to the digestion of starch • what happens to the nucleic acids in food • the role of Helicobacter pylori in gastric and duodenal ulcers
Practical	
explain the relationship between structure and function of mammalian stomach, ileum, liver and pancreas (exocrine and endocrine tissues) using histological sections and electron micrographs	Students should study prepared microscope slides and electron micrographs of the organs listed. They should be able to make labelled, low power plan drawings and labelled and annotated high power drawings of different cell types. Observations from slides should be compared with photomicrographs 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

Useful search terms
nervous system; central nervous system; peripheral nervous system; sensory neurone; motor neurone structure; resting potential; action potential; action potential myelinated; nerve impulse speed and temperature or myelin or diameter; synapse and excitatory or inhibitory or acetylcholine or adrenergic or GABA; brain functions; brain and names of individual components; pituitary and body or gland; cerebrospinal fluid; brain ageing; dementia; neuromuscular junction; striated muscle; skeletal muscle; muscle ultrastructure; sliding filament; actin myosin; innate behaviour; taxis kinesis; withdrawal reflex; instinctive behaviour; instinctive behaviour drosophila; habituation; imprinting behaviour; classical conditioning;

Useful search terms
operant conditioning; latent learning tolman; observational learning; insight learning; social behaviour primates

3.3 Nerves, muscles and behaviour	Notes
(a) describe the organisation of the central and peripheral nervous systems to include 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)	Students should be able to distinguish somatic, autonomic, sympathetic and parasympathetic divisions of the nervous system. The structure of the spinal cord and functions of motor and sensory neurones should also cover the reflex arc. The generation of resting and action potentials should be understood in terms of sodium ions, potassium ions, chloride ions and cytoplasmic proteins. Students should be familiar with depolarisation, repolarisation, hyperpolarisation, threshold, voltage-gated channels, all-or-nothing, absolute and relative refractory periods, and saltatory conduction.
(e) describe and explain transmission at chemical synapses including antagonistic excitatory and inhibitory neurotransmitters as exemplified by acetylcholine, noradrenaline and GABA	The antagonistic nature and role of EPSP's and IPSP's should be understood. • Acetylcholine: PNS role only. Stimulatory and inhibitory functions should be noted (linked to receptors). Cholinesterase should also be mentioned • Noradrenaline: the stimulatory role in the sympathetic nervous system • GABA: inhibitory role in the CNS (referring to hyperpolarisation). Specific details of different receptor types are not required, but students should be aware that different types of receptors are found in different cells/synapses.

3.3 Nerves, muscles and behaviour	Notes
(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) explain dementia and research into its possible causes, symptoms and treatments including stem cells	The functions of the parts of the brain could be summarised as a table. Dementia should be limited to a study of Alzheimer's and students should be aware of its range of symptoms and causes. Reduction in levels of acetylcholine should be mentioned as one possible cause. Plaques may also be mentioned and students should be aware of CJD. Treatments should include stem cell therapy and drugs to increase ACh.
(h) describe the structure and functioning of the neuromuscular junction and propagation of the action potential across muscle cells (i) describe the histology and ultrastructure of striated muscle and relate this to its contraction (j) describe and explain the sliding filament theory of muscle contraction to include the roles of calcium ions, ATP, actin, myosin, troponin and tropomyosin	Neuromuscular junctions should include reference to voltage sensitive calcium gates. Cardiac and skeletal muscle structure should include reference to T-tubules and sarcoplasmic reticulum in relation to calcium movement.

3.3 Nerves, muscles and behaviour	**Notes**
(k) explain the advantages of innate and learned behaviours to organisms (l) describe examples of genetically determined innate behaviours including taxes, kineses, withdrawal reflexes and instinctive behaviours (limited to foraging in Drosophila) (m) describe examples of learned behaviours widespread in the animal kingdom including habituation, imprinting, classical conditioning and operant conditioning (n) describe examples of social behaviour in primates and discuss the advantages of such behaviour	Examples that could be used: Taxes – movement of blowfly larvae away from light Kineses – movement of Hydra in response to food Withdrawal – touch response in Aplysia Instinctive – foraging in Drosophila melanogaster (the underlying genetics could also be covered as part of 1.6) Students should be able to give examples of learned and social behaviour and be able to explain how these relate to survival chances. The work of Lorenz and Pavlov should be mentioned.
Extension	• reception and transduction of stimuli in sense organs • the interplay of varied neurotransmitters in nervous system functioning • the role of ACh in REM sleep and Alzheimer's • the impact of psychoactive drugs on the nervous system • memory mechanisms • mental illness and its treatment • the behaviour of animals by observation (in the wild, in captivity and on screen) • the difficulties of observing ape behaviour without altering it • the contribution of primatologists in understanding primate behaviour. (e.g. Leakey's angels - Jane Goodall, Diane Fossey, and Biruté Galdikas – other primatologists e.g. Kinji Imanishi, Junichiro Itani, Tetsuro Matsuzawa, Barbara Smuts, Sue Savage-Rumbaugh)

3.3 Nerves, muscles and behaviour	Notes
Practical	
(i) explain the relationship between structure and function of spinal cord, brain (cerebral hemispheres and cerebellum only), nerves, myelinated neurones, synapses, neuromuscular junctions and striated muscle using histological sections and electron micrographs	Students should study prepared microscope slides and electron micrographs of the cells, tissues and organs listed. They should be able to make labelled, low power plan drawings and labelled and annotated high power drawings of different cell types. Observations from slides should be compared with photomicrographs and electron micrographs.
(ii) investigate innate behaviour using choice chambers and suitable motile invertebrates	Suitable invertebrates are woodlice, blowfly larvae and crickets. Choice chambers and other simple apparatus can be used to investigate taxes, kineses and reflexes. Further information is available from the Association for the Study of Animal Behaviour: http://asab.nottingham.ac.uk
(iii) use simple T mazes to investigate operant conditioning using suitable motile invertebrates	Students could make simple T mazes for these investigations.

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

Useful search terms
homeostasis; negative feedback; liver and functions or each individual function; hepatocyte

Useful search terms
kidney and anatomy or histology or ultrastructure or functions or excretion or osmoregulation or ultrafiltration or selective reabsorption or countercurrent multiplier; antidiuretic hormone; cell signalling; cell signalling cascade; receptors and G protein or ADH or adrenaline or glucagon

3.4 Homeostasis and cell signalling	Notes
(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, detoxification and heat generation (c) explain the actions of insulin and glucagon on the hepatocyte to include the role of membrane receptors and second messengers as well as membrane permeability to glucose (d) outline the causes, diagnosis, effects and treatment of types 1 and 2 diabetes	Students should know the structure of lobules within the liver, including reference to hepatic portal vein, hepatic vein, artery, sinusoid and bile duct. Liver function should include: • Blood sugar control: Students should be familiar with gluconeogenesis, glycogenolysis and glycogenesis, as well as the roles of insulin and glucagon. Reference to membrane receptors should be limited to knowledge that different receptors exist for insulin and glucagon and each causes different second messengers to be activated (refer to 3.4(h)). Membrane permeability should be mentioned in terms of glucose transport proteins being made available for facilitated transport • Deamination: Limited to knowledge of the removal of an amino group from excess amino acids producing ammonia (and then urea by addition of carbon dioxide) and organic acids (link to respiration) • Transamination: Conversion of one amino acid into another. Students should be familiar with the idea of essential and non-essential amino acids. Details of specific transamination reactions are not required • Detoxification: Removal of metabolic wastes (lactic acid and ammonia) and other poisons from the blood • Heat generation: Reference should be made to the high level of metabolic activity in hepatocytes • Others: Students should also be aware of the liver's role in bile production and lipid metabolism (LDL/HDL). Could be linked to 3.1(f).

3.4 Homeostasis and cell signalling	**Notes**
(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 multiplier (f) describe the role of the hypothalamus, posterior pituitary and ADH in osmoregulation	A good understanding of kidney structure and function is expected and students should be able to explain the role of ADH in terms of protein channels in the collecting ducts. The two solute model of kidney function is described in section 44.4 of Campbell and Reece (see Appendix 2). This describes how urea and sodium and chloride ions maintain an osmotic gradient between the collecting ducts and interstitial fluid in the medulla.
(g) outline the principles of cell signalling in terms of: • ligand-receptor interaction • signal transduction • enzyme cascade and amplification • change in cell functioning (h) outline the functioning of G-protein receptors in transduction of signals including increased extracellular ADH and glucagon concentrations	Students are required to have a basic level of understanding of cell signalling: • Ligand-receptor interaction: students should be aware that ligands (hormones, neurotransmitters and growth-factors) bind to specific cell surface receptors • Signal transduction: students should understand that stimulation of a receptor causes the activation of a second molecule within the cell (G-proteins for example) • Enzyme cascade and amplification: students should understand how G proteins go on to release second messenger molecules which initiate a series of reactions within the cell, including phosphorylation, activation or inhibition of enzymes and control of transcription • Change in cell function: this cascade of events can produce a change in cell function such as activation of ion channels by ADH or glycogenolysis by glucagon • ADH and glucagon – students should be able to explain the mode of action by referring to: G-proteins, adenylate cyclase, cAMP and protein kinases.

3.4 Homeostasis and cell signalling	**Notes**
Extension	• other homeostatic systems such as thermoregulation • the interplay of nervous and hormonal control in homeostasis • the applicability of the idea of homeostasis to organisms in other Kingdoms, to populations, to communities, to ecosystems and, with reference to Lovelock's Gaia hypothesis, to the biosphere • other cell signalling pathways such as the insulin receptor tyrosine kinase pathway
Practical	
(i) examine the gross structure of the kidney	Kidneys should be obtained from a butcher or an abattoir to show renal blood vessels and the base of the ureter. Students can dissect away surrounding fat and connective tissue to reveal these and then dissect the kidney to show the different regions and trace blood vessels through the kidney tissues. They should make a low power plan diagrams of the regions of the kidney from different vertical and horizontal sections.
(ii) examine the detailed structure of the nephron with associated blood vessels using histological sections and electron micrographs	Students should study prepared microscope slides using hand lenses and microscopes. They should make labelled and annotated high power drawings of cells from the glomerulus and different regions of kidney tubules. Observations from slides should be compared with photomicrographs and electron micrographs.
(iii) investigate examples of homeostasis, such as control of heart-rate and osmoregulation	Students can use heart rate monitors and data logging software to record their heart rate and analyse and interpret changes in heart rate with changes in activity. The changes can be explained with reference to energy requirements, muscular activity, respiration rates, oxygen supply, carbon dioxide and lactate removal from muscles. They can also investigate changes in volume and colour of urine with changes in water intake, activity and ambient temperature.

3.5 The immune system

Content

Structure, function and physiology of the mammalian immune system
Monoclonal antibodies

Useful search terms
non specific immunity; immune system; B cell T cell; plasma cells; memory cells; antibody structure; antibody IgG; immunity and passive or active or natural or artificial; immunisation or vaccination and polio or smallpox or measles or tetanus; ABO blood group; blood transfusion; hyperacute rejection; histocompatibility; monoclonal antibodies; monoclonal antibody production; monoclonal antibody hybridoma; monoclonals and pregnancy and HIV/AIDS diagnosis and radioimmunotherapy

3.5 The immune system	Notes
(a) contrast the specific and non-specific immune systems	Non-specific immunity should cover anatomical features (barriers to infection such as mucus membranes and lysozyme), humoral (inflammatory response including interleukins and interferon) and cellular (phagocytosis by neutrophils and macrophages). Details of the complement system are not required.

3.5 The immune system	Notes
(b) outline the role of B-cells, plasma cells, memory cells, helper-T cells and cytotoxic-T cells in giving specific immune primary and secondary responses (c) discuss the structure and action of antibodies (including variable and non-variable regions of the monomeric immunoglobin IgG, but not including the range of types and functions of immunoglobulins)	Students should have a good level of understanding of specific immunity but limited to the cell types specified. Activation of B and T cells should refer to antigen presentation.
(d) distinguish between active and passive immunity, as well as natural and artificial immunity, limited to specific examples including 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	• Tetanus: vaccination with tetanus toxoid • TB: BCG vaccination with attenuated pathogen • Polio: OPV and IPV vaccinations • Measles: MMR vaccination with attenuated viruses • Malaria: Students should be familiar with Anopheles sp. and Plasmodium sp. and have a basic understanding of the parasite's life cycle. Problems such as parasite drug resistance, insecticide resistance, drug cost and side effects should be considered. The difficulties in developing vaccines against parasites should be appreciated.
(f) explain the term autoimmune disease with reference to type 1 diabetes and myasthenia gravis	• Type I diabetes: autoimmune rejection of beta cells in the islets of Langerhans • Myasthenia gravis: antibody blockage of acetylcholine receptors at neuromuscular junctions.
(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)	Hyperacute rejection (immediate rejection involving the pre-existing ABO antibodies) and acute rejection could be looked at in reference to kidney transplantation.

3.5 The immune system	Notes
(i) outline the production of monoclonal antibodies and explain why it is necessary to use hybridoma cells for this purpose (j) discuss and evaluate the use of monoclonal antibodies compared to conventional methods for diagnosis and treatment including pregnancy testing, diagnosis of HIV/AIDS and radioimmunotherapy of cancer	The fusion of spleen B cells and myeloma cells to produce hybridoma clones should be understood. The use of selective media should be noted but details of HAT and HGPRT are not required. • Pregnancy testing: HCG monoclonal antibodies • HIV/AIDS diagnosis: the use of monoclonal antibodies to detect HIV capsid proteins should be described. • Radioimmunotherapy: the use of monoclonal antibodies (such as Ibritumomab tiuxetan) to deliver radioactive doses to cancer cells should be understood.
Extension	• the process of setting up the immune system in early life of a mammal • conditions which appear to be likely to be autoimmune diseases such as multiple sclerosis (MS) or Crohn's disease • the role of the immune system and antigens in allergies • the difficulties of ensuring tissue matching between donors and recipients in transplants • the implications of differences between the ABO and Rhesus blood groups of mother and fetus • the impact of monoclonal antibodies on diagnosis and treatment
Practical	
X ref Section 3.1, Practical Learning outcome (i)	Students could study electron micrographs of plasma cells as good examples of protein-synthesising cells.

3.6 Reproduction

Content

Human sexual reproduction
Cloning

Useful search terms
meiosis; telomere; somatic cell cloning; Dolly the sheep; male human urogenital system; male reproductive system; female human urogenital system; female reproductive system; oestrogen; progesterone; follicle stimulating hormone; luteinizing hormone; menstrual cycle hormones; in vitro fertilisation; in vivo fertilisation; placenta; placenta functions; chorionic gonadotrophin; lactogen hormone; cloning ethics; SCNT; embryo splitting

3.6 Reproduction	Notes
(a) outline the structure of the human male and female urinogenital systems (b) explain the roles of ovarian and anterior pituitary hormones in controlling the menstrual cycle (limited to oestrogen, progesterone, FSH and LH)	Students should have a good understanding of the structure and functions of the male and female urinogenital systems, but knowledge of gametogenesis is not required.
(c) explain what is meant by in vitro and in vivo fertilisation	Students should be able to describe the process of IVF but technical details are not required. In vivo fertilisation should be described including the role of the zona pellucida and the acrosome (details of capacitation are not required).

3.6 Reproduction	Notes
(d) 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)	Details of the functions of placental hormones should be limited to: • Chorionic gonadotrophin: maintains the corpus luteum (and hence progesterone levels) • Oestrogen and progesterone: maintenance of pregnancy • Human placental lactogen: increases blood glucose for fetal development (a link with insulin could be made).
(e) 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)	The stages of somatic cell nuclear transfer should be described. The uses of embryo splitting (for IVF and cattle cloning) should also be considered. Therapeutic cloning could cover examples such as possible treatment for Alzheimer's or Parkinson's disease.
Extension	• somatic cell cloning and telomere length (including evidence for premature arthritis in Dolly the sheep) • the evolutionary significance of sexual reproduction and parasite pressure • the cost to organisms of sexual reproduction • the difficulties for fertilisation for terrestrial organisms • differences between and advantages of sexual and asexual reproduction • the use of synthetic analogues of natural hormones in increasing or decreasing human / mammalian fertility • the effects of drugs and infectious agents on fetal development
Practical	
explain the relationship between structure and function of mammalian testis, ovary (including follicles and corpus luteum) and placenta using histological sections and electron micrographs	Students should study prepared microscope slides and electron micrographs of the testis and the ovary at various stages of the ovarian cycle. They should be able to make labelled, low power plan drawings of the two organs and labelled and annotated high power drawings of follicles and a seminiferous tubule to show different cell types. Observations from slides should be compared with photomicrographs and electron micrographs. Students should also view sections of the placenta and study photomicrographs and electron micrographs to study the relationship between structure and function.

Opportunities for independent learning:
It is expected that students should carry out independent learning including; posters, booklets, audiovisual presentations, summarising an aspect of a topic or other means of communicating information. This could be made available to the group and others who are interested, as part of a group display using wall space or audiovisual media as appropriate, or as a synoptic revision exercise.

aspects of the physiology of animals, such as aspects of sexual reproduction in mammals;
the evolution of the immune system;
the uses of monoclonal antibodies;
different feeding strategies and adaptations.

4. THE LIFE OF PLANTS

These questions may be put to candidates to stimulate discussion and prompt and direct their own researches while covering Section 4.

- How do plants transport materials?
- How does water get to the top of a redwood tree that is over 110 m high?
- Why are plants called producers?
- Why do we neglect plants 'at our peril'?
- How do plants control themselves?
- Why do some plants produce flowers, seeds and fruits?

4.1 Transport in plants

Content

Transport of water through plants
Transport of assimilates in the phloem
Stomata – structure and function

Useful search terms
xylem structure function; xylem cohesion tension; phloem structure function; phloem mass flow; stomata; stomatal mechanism; abscisic acid; vascular wilt

4.1 Transport in plants	Notes
(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	This should include: • movement of water into a root hair cell (including active transport of mineral ions) • movement across cells (apoplastic and symplastic routes) including reference to plasmodesmata • function of the endodermis • movement of water along xylem and into leaf cells • importance of spongy mesophyll and evaporation of water via stomata.
(d) describe the structure and function of guard cells (e) explain the mechanism of opening and closing of stomata	The mechanism of opening and closing of stomata should be explained, limited to a description of proton pumps and potassium ions affecting the water potential of the guard cells.
(f) explain the effect of vascular wilt diseases of plants (including Panama disease of bananas)	The commercial importance of vascular wilt diseases should be appreciated. Panama disease (or Fusarium wilt - the blockage of xylem by pathogenic fungi) should be described.
(g) describe the structure and function of phloem tissue and explain the relationship between its structure and function (h) explain mass flow in phloem	The structure of phloem sieve tubes and companion cells should be described. Students should be able to explain mass flow in terms of sink, source, hydrostatic pressure and the transpiration stream.
Extension	• the interplay between cohesion/tension, capillarity and root pressure in transport of water in plants • guttation • evolution of xylem • secondary thickening • transport cells in phloem • symplast phloem loading and the polymer trap mechanism for phloem transport • other vascular wilt diseases

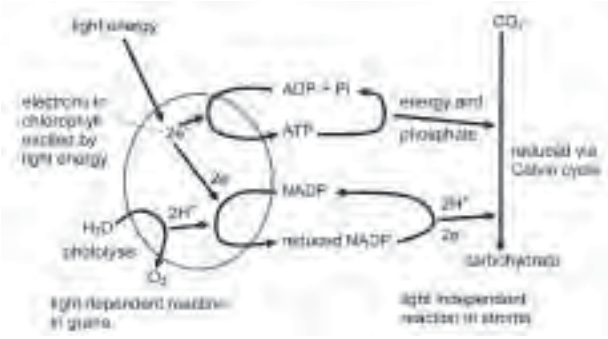
4.1 Transport in plants	Notes
Practical	
explain the relationship between structure and function of xylem and phloem using histological specimens from plant transport systems including prepared slides and electron micrographs	Students should study prepared microscope slides and electron micrographs of xylem and phloem. They should be able to make labelled, low power plan drawings of roots, stems and leaves to show the distribution of these tissues and labelled and annotated high power drawings of different cell types. Observations from prepared slides should be compared with photomicrographs and electron micrographs. Students can also make temporary preparations of xylem tissue in organs such as petioles of celery and stain for the distribution of lignin.

4.2 Photosynthesis

Content

Light-dependent stage
Light-independent stage
Photorespiration

Useful search terms
photosynthesis; photosynthesis and light dependent or light independent; C3 photosynthesis; photosynthetic pigments; photosynthetic pigments chromatography; antenna pigments; light harvesting complex; photophosphorylation; Calvin cycle; carbon fixation; rubisco; rubisco photorespiration; photorespiration temperature; C4 plants; CAM plants

4.2 Photosynthesis	Notes
(a) explain the relationship between the light-dependent and light-independent stages of photosynthesis within the chloroplast of a C3 plant (b) use chromatography to identify key photosynthetic pigments (limited to chlorophylls a and b, carotene and xanthophyll) and interpret absorption and action spectrum graphs	Summarise the movement of NADP/reduced NADP and ATP/ADP between the stroma and grana of the two stages. 
(c) explain the distribution of photosynthetic pigments and their function inside the C3 chloroplast	This should refer to the accessory pigments (such as chlorophyll b, carotene and xanthophyll) transferring energy to reaction centre made up of chlorophyll a.
(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 1 and 2, electron transport chain, generation of proton gradient, cyclic and non-cyclic photophosphorylation)	Reference should be made to the photolysis of water, photophosphorylation (involving PSII and PSI) and the generation of a chemiosmotic potential. Students should be able to relate the processes of non-cyclic photophosphorylation with the structure of a chloroplast.
(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	The Calvin (or Calvin-Benson) cycle should be understood limited to the intermediates mentioned. Students should be aware of the fate of the products of photosynthesis including the production of glucose, sucrose, cellulose and starch from TP, glycerol from TP, fatty acids from GP → pyruvate and amino acids from GP → pyruvate → acetyl CoA and the Krebs cycle.

4.2 Photosynthesis	Notes
(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 and CAM 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 [C4] and temporal separation [CAM]. Biochemical details of the C4 pathway are not required)	Students should be able to describe the competition between carbon dioxide and oxygen and the subsequent reduction in efficiency due to photorespiration of the 2C product. The increase in photorespiration at higher temperatures and light intensities should be linked with the distribution and advantages of C4 plants.
Extension	• what the vulnerability of rubisco to photorespiration suggests about the nature of the atmosphere when rubisco originated • use of radiotracers and two-way chromatography in elucidating the Calvin cycle • light harvesting and the role of the various pigments, proteins and cofactors involved • the details of the regeneration and cycling of carbon compounds in the Calvin cycle • comparative biochemistry of C3, C4 and CAM plants • distribution of C3, C4 and CAM plants
Practical	
(i) investigate the Hill reaction using a chloroplast suspension and DCPIP	This practical protocol can be carried out in test-tubes or with tiny volumes of chloroplast suspension in melting point tubes.
(ii) investigate the structure of chloroplasts using electronmicrographs	Students should investigate chloroplast structure by viewing different sections of chloroplasts.
(iii) carry out paper or thin layer chromatography to separate and identify key photosynthetic pigments	Students should calculate R_f values from their one-way chromatograms. This exercise would be useful to do before introducing electrophoresis (see Section 1.7). Two-way chromatography could also be introduced.

4.2 Photosynthesis	Notes
(iv) compare the leaf anatomy of C3 (e.g. Ligustrum, Triticum), C4 (e.g. Zea mays) and CAM (e.g. Crassula) plants under the light microscope	Students should study prepared microscope slides and electron micrographs of leaves of the species listed. They should make labelled low power plan drawings. These can be annotated to show how the structures or the leaves are adapted to survival.

4.3 Reproduction

Content

Pollination
Fertilisation
Seeds and fruit

Useful search terms
pollination; self-pollination; cross-pollination; wind pollination; insect pollination; pollen tube; pollen tube chemotropic; seed structure; fruit structure

4.3 Reproduction	Notes
(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	Details should be limited to flowering plants only and no details of alternation of generation are required. Knowledge of the structure of the flower in monocotyledons and dicotyledons is expected in terms of differences in wind and insect pollination. Mechanisms to prevent self-fertilisation should be described.
(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).	This should include reference to the megaspore dividing to form the embryo sac, formation of the ovule and structure of pollen. This may be combined with the section on meiosis (1.5 (g)).
Extension	• the implications for a plant species of being dioecious or monoecious • double fertilisation in flowering plants, relating this to the functions of endosperm and embryo • advantages of endospermous and non-endospermous seeds • seed dispersal • vegetative propagation

4.3 Reproduction	Notes
Practical	
(i) investigate pollination mechanisms and pollen structure as well as growth of the pollen tube in living pollen	Students should study a range of flowers to investigate pollination different mechanisms. Pollen grains from different species should be viewed with the light microscope and in scanning electron micrographs. Pollen tubes should be grown and growth rate can be determined.
(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	Seeds of different species should be studied. The biochemical contents of these different seeds could be studied (see 2.2(ii)).
(iv) investigate seed and fruit development using fresh specimens and prepared slides of Shepherd's purse, Capsella bursa-pastoris	Flowers, fruits and seeds of Shepherd's purse can be collected and used for analysing the development of these structures. Embryogenesis in this species can be followed by using prepared slides. Students should be able to identify stages in this development.

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

Useful search terms
gibberellin; auxin; gibberellin transcription; auxin transcription; gibberellin DELLA; DELLA proteins; phototropism stem auxin; auxin transport; auxin efflux; crown gall and agrobacterium

4.4 Control of plant processes	Notes
(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	The regulation of plant cell growth should be taught with reference to regulation of the cell cycle covered in 1.3 and 1.6 i.e. the importance of transcription and gene regulation in cell division. The presence of transcription blocking factors (DELLA proteins) should be described. Detail of specific genes and pathways for gibberellin (GA) and auxin (IAA) are not required. Students should be able to explain results from experiments that demonstrate the growth promoting properties of IAA (e.g. Darwin's and Went's experiments). Similarly, experiments with plants treated with GA should be described and linked to gibberellin's role in 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	Students should be able to explain why failure to produce gibberellins or DELLA proteins would result in dwarf varieties. Students should also be able to describe how GA activates ubiquitin which binds onto the inhibitory DELLA proteins. This in turn leads to the DELLA proteins being destroyed by proteasomes (already covered in 1.1 and 2.1) and thereby removing the inhibition.
(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	Simple monohybrid inheritance of **Le/le** alleles leading to tall/short plants could be covered as part of 1.6.
(f) explain the role of auxins in positive phototropism of stems	The effect of light on the movement of auxins from cells in the stem through transmembrane protein channels (efflux transporters) should be understood.
Extension	• other effects of auxins and gibberellins • other plant growth substances and control systems • applications of plant growth substances in horticulture and agriculture • how our understanding of phototropism of stems has developed from Darwin's original experiments to the present day molecular and membrane perspective

4.4 Control of plant processes	Notes
Practical	
(i) investigate phototropism in coleoptiles or other young shoots including unilateral application of auxin from excised coleoptile tips or auxin in a gel	Students can grow oat seedlings and treat them as shown. They can also use a variety of different wavelengths of light and research the molecular mechanism of phototropism.
(ii) investigate the effect of gibberellins on dwarf/bush pea or sweet pea seedlings	Treat dwarf plants and rosette plants, such as the rosette mutant of Brassica rapa ('fast plant'), with gibberellin solutions. This could be more than a demonstration by using different concentrations of gibberellin and measuring the effects on growth. Students could measure total height and internode lengths of plants.
(iii) investigate whether plants with a basal rosette of leaves have non-functional gibberellin genes by adding gibberellins	

Opportunities for independent learning:
It is expected that students should carry out independent learning including; posters, booklets, audiovisual presentations, summarising an aspect of a topic or other means of communicating information. This could be made available to the group and others who are interested, as part of a group display using wall space or audiovisual media as appropriate, or as a synoptic revision exercise.

C3 photosynthesis;
comparison of C3, C4 and CAM plants;
the position of meiosis in the plant life cycle;
aspects of sexual reproduction in flowering plants or the role of plant growth substances.

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 residential field course, or for situations where this is not possible, could be accomplished by a series of fieldwork sessions in the local environment, 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 organisms to the niches that they occupy.

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).

These questions may be put to candidates to stimulate discussion and prompt and direct their own research while covering Section 5.

- What defines where a particular organism lives and what it does there?
- How does adaptation relate to success for organisms/species?
- Why are tropical ecosystems so different from temperate and polar ones?
- Explain why large fierce animals are rare and why they should be conserved?
- How many species are there? And why are there so many?
- What is the smallest part of an ecosystem that can be conserved successfully?

5.1 Adaptation

Content

Adaptation and the ecological niche

Useful search terms
adaptation biology; adaptation and name of chosen organism; ecological niche; adaptive behavioural strategy; behavioural ecology; dunnock strategies; red deer sex ratio; C4 plant distribution; climate change agriculture C4 photosynthesis; adaptations and hydrophytes or xerophytes or mesophytes

5.1 Adaptation	Notes
(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)	Adaptations in birds could include the musculature of starling's beaks or the wide range of sexual strategies (monogamy, polyandry, polygyny, polygynandry) and display behaviour used by hedge sparrows (dunnock). Adaptations in protoctists could include their reproductive, movement or feeding strategies in specific environmental conditions. Behavioural adaptations could include chemotaxis, thermotaxis, phototaxis or geotaxis.
(b) discuss how the niche concept and adaptation explain the distribution of organisms within habitats	The niche should be described and defined.
(c) explain how an individual's adaptive behavioural strategy can vary within a species, making particular reference to dunnock and red deer	Dunnock behaviour varies from one individual to another and this could be related to survival strategy. Rutting behaviour in red deer should also be described.
(d) explain the global distribution of C3 and C4 plants and discuss the potential impact of climate change on future patterns of agriculture (e) discuss the stomatal and other adaptations characteristic of flowering plant species living in a variety of habitats (including hydrophytes and xerophytes)	The distribution of C4 plants in hot and dry habitats should be described as an indication of the adaptive advantage of this type of biochemistry. This could be related to past and future climate change and possible implications on world agriculture and food supply. Typical adaptations seen by hydrophytes and xerophytes should be described and students should be able to relate these to survival strategy. Adaptations might include: • Hydrophytes: reduced cuticle, roots and strengthening tissues, air filled cavities in leaves and hollow stems • Xerophytes: reduced surface area, loss of leaves, dormancy, water storage, stomatal changes and epidermal hairs or waxes.
Extension	• restrictions on niche size by adaptation/specialisation and interspecific competition • the effect of invasive species on isolated communities • are all features adaptive? • varied ecological perspectives • distribution of CAM plants

5.1 Adaptation	Notes
Practical	
(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	Students should carry out investigations on at least three species from different habitats and report their findings to the rest of the class. These investigations are best carried out in the field or on a visit to a wild life park, zoo or botanical garden and are best not restricted to animals. The studies could combine detailed study of structures, e.g. leaf anatomy and histology, with physiological adaptations to environment.
(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)	Study of cross sections of leaves should be complemented by study of whole leaves and distribution of stomata. Studies of whole specimens and cross sections should be supplemented by photomicrographs and electron micrographs.

5.2 Measuring and conserving biodiversity

Content

Biodiversity
Sampling techniques as ecological tools
Principles of conserving biodiversity
The species-area concept
Integrated management strategies

Useful search terms
quadrat; ecological sampling; diversity index; Lincoln index; mark capture recapture; conservation species; conservation biodiversity; keystone species; species area relationship; habitat fragmentation; wildlife corridors; SLOSS debate

5.2 Measuring and conserving biodiversity	Notes
(a) explain what is meant by biodiversity with reference to different levels; ecosystem, community, species and genetic	Students should understand that biodiversity can refer to ecosystems or the make-up of the communities of organisms within those ecosystems and not just the diversity of species present. Genetic biodiversity could include discussion of captive breeding, inbreeding, disease and evolutionary advantages.
(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, relative abundance scales (e.g. ACFORN) (c) explain how to estimate population size using mark-release-recapture and the Lincoln index	Students should be familiar with Simpson's index of diversity and be confident in selecting a suitable means of gathering data in the field (using quadrat sampling techniques). The web page **www.countrysideinfo.co.uk/simpsons.htm** should be consulted before using diversity indices. Students should also be able to estimate population sizes using the Lincoln Index and be able to discuss the possible causes of over and underestimates of population size.
(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	Conservation benefits might include the preservation of biodiversity for agriculture, medicine and industry, as well as environmental considerations and cultural, leisure, ethical and aesthetic reasons. Conservation has limited value unless details of current biodiversity and population estimates are known. The conservation of keystone species should be highlighted and their importance in different ecosystems discussed. Examples might include beavers, Pacific sea otters and coyotes.

5.2 Measuring and conserving biodiversity	**Notes**
(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]	Students should be aware of the preference for conservation of large nature reserves as opposed to several smaller sites. The effects of habitat fragmentation on population viability should be discussed. The work of the Biological Dynamics of Forest Fragments Project could also be discussed, together with the development of habitat corridors (the China-Russia Tiger corridors for example). The SLOSS debate – whether a single large reserve will conserve more species than several small reserves - of the 1970s and 1980s never came to a resolution. Students can discuss the evidence for and against by reference to specific reserves.
Extension	• measuring biomass • measuring productivity • the limitations of the various means used to measure the quantity of organisms • the difficulties of measuring the population of large, mobile animals living in extreme conditions such as polar bears, tigers, pandas, blue whales and oryx • the possible reasons for the existence of biodiversity hotspots, especially in the tropics • the importance of conserving biodiversity hotspots • the relationship between conservation and local communities
Practical	
(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	Students should apply these techniques to one or more ecosystems; these sampling techniques should be combined with other sections of the syllabus such as adaptations, classification and use of keys. Data should be collected and presented in appropriate ways, e.g. kite diagrams to show changes along a transect.
(ii) determine the diversity of an ecosystem by calculating Simpson's index of diversity or another appropriate index	Diversity indices are best calculated on two or more areas, such as sheltered and exposed shore, grazed and ungrazed grassland so that they can be used in an investigation rather than just calculated as an end in itself.

5.2 Measuring and conserving biodiversity	Notes
(iii) determine the population of a small animal using the mark, release recapture method and calculate the Lincoln index (alternatively this may be modelled)	Care should be taken for the welfare of the animal chosen for this investigation.

Opportunities for independent learning:
It is expected that students should carry out independent learning including; posters, booklets, audiovisual presentations, summarising an aspect of a topic or other means of communicating information. This could be made available to the group and others who are interested, as part of a group display using wall space or audiovisual media as appropriate, or as a synoptic revision exercise.

biodiversity;
a field-course report;
aspects or examples of adaptation to niches;
tropical ecology;
aspects of conservation;
adaptive behavioural strategies or other ecology-related topics of interest to the individual.

Appendix 1: Practical Assessment

INTRODUCTION

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

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

Practical Assessment will be through Component 3, a practical examination paper. Candidates should keep records of the practical work they carry out during their course.

The planning aspect of Practical Assessment will be examined in Component 2 along with data analysis, interpretation and evaluation. Component 3, a practical examination paper, will not formally assess planning, but will assess all the other skills described below. Candidates will not be presented with a complete set of instructions to follow in the practical examination: they will be expected to make decisions about such things as concentrations to prepare and number of measurements to take. Experience of planning and carrying out investigations will be essential preparation for the practical examination.

It should be stressed that candidates cannot be adequately prepared for planning, data analysis, interpretation and evaluation in Component 2 and the Practical Assessment in Component 3 without extensive laboratory work during their course of study.

Many of the practical activities listed in the syllabus are suitable for developing the skills itemised in this appendix. For many of these candidates could:

- plan, implement and evaluate an investigation;
- carry out sufficient preliminary practical work to inform making a plan;
- carry out a protocol, collect results which are then analysed and evaluated.

COMPONENT 3

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, drawing and magnification calculations from unfamiliar structures or specimens;
- making observations and deductions from photographs, photomicrographs, electron micrographs and specimens.

Component 3 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.

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, to draw up tables, charts, graphs and other appropriate means of presenting the data and to analyse it to draw appropriate conclusions and evaluate procedures and data.
It will focus on the following experimental skills:

- manipulation of apparatus;
- decision-making;
- recording observations and measurements;
- presentation of data;
- calculations, e.g. rates of reaction;
- analysis of data – experimental results and secondary data;
- evaluation of procedures and data;
- suggesting improvements;
- concluding.

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

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

Section B will consist of two or three short questions totalling 40 marks. It should be completed in 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 they have made themselves as temporary mounts or which are provided as prepared slides. Candidates will also be provided with secondary data to analyse and interpret. These secondary data may be in the form of photographs, drawings, diagrams, tables and graphs. Section B will concentrate on the following skills:

- decision making;
- observation;
- presentation of information in the form of plan diagrams, drawings, tables, etc.;
- calculations, e.g. magnifications and actual sizes;
- analysis and interpretation;
- evaluation.

Throughout their course, candidates should be given opportunities to make decisions about their practical work. This might involve choosing the number of values of the independent variable and the number of replicates. It might also involve deciding how to make up dilutions. They should also plan complete experiments to include methods of data collection and analysis. Candidates taking the practical examination will be expected to have the appropriate skills involved in decision-making and planning even though candidates will not be expected to plan a complete experiment in this examination.

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

Some questions in Section B 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 Cambridge Pre-U syllabus. Information that candidates are not expected to know, to permit candidates to use the data, will be provided in the examination paper. The amount of information will be limited to ensure that there is ample time for candidates to read and consider the information.

Candidates may start with Section A or Section B. They will need the use of a microscope in Section B for at least 30 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.

Assessment of skills in Component 3

The practical examination will test four skill areas. The table below lists the skill areas, relevant sub-skills and the approximate number of marks that will be awarded for each skill. Each skill may be assessed in both sections of the examination paper. The table also includes planning and decision-making that is assessed in Component 2 but which are central to a development of the other skills. Details of the sub-skills are given in the next few pages.

Skill	***Sub-skills***	***Total marks***
Planning and decision-making	• Defining the problem • Choosing appropriate techniques • Determining number of measurements / observations to take	n/a assessed in Component 2
Manipulation, measurement and observation	• Successful collection of data and observations • Decisions about measurement or observations	25
Presentation of data and observations	• Recording data and observations in tables and other suitable forms • Presenting data in the form of graphs and charts	15
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	25
Evaluation of procedures and data	• Identifying limitations and sources of error • Suggesting improvements	15
Total marks		80

Planning and decision-making

Defining the problem

Candidates should be able to:

- identify the dependent and independent variable in an investigation or experiment;
- express the aim in terms of a prediction or hypothesis, and express this in words and in the form of a predicted graph;
- identify the variables that are to be controlled;
- decide on a control experiment or experiments (if appropriate).

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

Choosing appropriate techniques
Candidates should be able to:

- describe the method to be used to vary the independent variable, and the means that they will propose to ensure that they have measured its values accurately;
- describe how the dependent variable is to be measured;
- describe how each of the other key variables is to be controlled;
- explain how any control experiments will be used to verify that it is the independent variable that is affecting the dependent variable and not some other factor;
- describe the arrangement of apparatus and the steps in the procedure to be followed;
- suggest appropriate volumes and concentrations of reagents, and explain how different concentrations would be prepared;
- assess the risks of their proposed methods;
- describe precautions that should be taken to keep risks to a minimum;
- draw up tables for data that they might wish to record;
- describe how the data might be used in order to reach a conclusion.

The overall arrangement should be workable. It should be possible to collect the data required without undue difficulty if the apparatus were assembled as described. Words and labelled diagrams should be used for describing the apparatus and how to use it. The measuring instruments chosen should measure the correct quantity to a suitable precision. Control experiments may be of the type where all factors are identical to the experimental treatment, except that the value of the independent variable is zero, or they may be of the type used to confirm that, for example, it is an enzyme that is causing a particular effect, where the enzyme is omitted or denatured.

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

- in % (w/v), e.g. by adding a known mass of solute to a small volume of solvent, mixing until fully dissolved and then making up to the final volume with solvent;
- in mol dm^{-3}, by dissolving the molar mass of solute and then making up to 1 dm^3 with solvent;
- by using serial dilution to make up a wide range of dilutions, e.g. by factors of 2 or 10;
- by proportional dilution in order to make up a narrow range of dilutions.

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

Candidates should be able to describe the main steps that they would use in order to get to the point of being able to draw conclusions, including, as appropriate, preparation of results tables, proposed graphs to plot, key points to consider in any evaluation of the method and results, and reference back to the hypothesis.

Determining number of measurements / observations to take
Candidate should be able to:

- choose a suitable range of values for the independent variable in an investigation;
- choose a suitable number of intermediate values for the independent variable;
- decide how many replicates to take of each value of the independent variable to ensure reliability (reproducibility) of results;
- decide how many observations to take in an investigation that generates qualitative data.

Candidates should apply their knowledge and understanding of methods of analysis and evaluation to ensure they plan to take enough readings of the independent variable to be able to draw a graph and/or make valid conclusions. They should also be aware of the variability of results in biological investigations so that they plan to take enough replicates to carry out a statistical analysis (see p.110–111). These skills will also be tested in Section A of the practical examination where they are required to make decisions about the number of measurements to take and comment on this aspect when evaluating. These skills will also be tested in Section B where observations and/or measurements have to be made.

Manipulation, measurement and observation

Successful collection of data and observations
Candidates should be able to:

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

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

Marks may be awarded for:

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

It is important that sufficient distinct observations are made, for example to:

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

Candidates will be expected to use light microscopes. They should be able to place the slide on the stage, arrange the lighting appropriately and focus on the specimen at both low-power (X10, sometimes described as 16 mm or 2/3") and high-power (X40, or 4 mm or 1/6") using a microscope with a graticule fitted into the eyepiece.

Decisions about measurements or observations
While carrying out an investigation, candidates should be able to:

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

Candidates may need to choose how many tests, measurements and observations can be made in the time available. In some experiments a regularly-spaced set of measurements will be appropriate. For other experiments, such as those requiring the peak value of a curved graph to be determined, it may be appropriate for the measurements to be concentrated in one part of the range investigated. Candidates will be expected to be able to identify the most appropriate distribution of values. In qualitative experiments, precise descriptions and comparisons of colour or other observations are expected.

In experiments, such as those involving enzymes:

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

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

Presentation of data and observations

Recording data or observations in tables and other suitable forms
Candidates should be able to:

- present numerical data, values or observations in a single table of results;
- draw up the table before taking readings/making observations, so that candidates can record directly into the table, to avoid the need to copy up their results;
- make tables of data and observations large enough so that all the entries can be comfortably fitted in the available space;
- include in the table of results, if necessary, columns for raw data, for calculated values and for deductions;
- use column headings that include the quantity and the unit (as appropriate) and that conform to accepted scientific conventions;
- record raw readings of a quantity to the same degree of precision and observations to the same level of detail;
- follow the Society of Biology recommendations for constructing tables;
- make drawings large and un-shaded so that errors are small, and use fine, clear, unbroken lines, showing clear outlines of structures;
- use pencil for drawings and, lines on tables.

As an example of accepted practice in column headings, if the quantity being measured is length in millimetres, then this should be expressed as 'length/mm' or 'length (mm)'.

Headings such as 'length', 'length mm', or just 'mm' are not acceptable. The quantity or the unit or both may be written in words or appropriate symbols may be used provided that their meaning is clear and unambiguous in the context. Avoid t, since it may be used for time and for temperature. Conventional symbols or abbreviations such as r for radius, may be used without explanation.

In recording data and observations, if one measurement of length in a column of raw data is given to the nearest millimetre, then all the lengths in that column should be given to the nearest millimetre. The degree of precision used should be compatible with the measuring instrument used: it would be inappropriate to record a distance measured on a millimetre scale as '2 cm' or a time to 1/10th of a second. Where the calibration marks on a measuring instrument are widely spaced, it may be appropriate to interpolate between the marks, but where the calibration marks are close together then the reading should be to the nearest calibration mark. See **www.chemsoc.org/networks/learnnet/RSCmeasurements.htm** for more information on measurement.

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

Presenting data in the form of graphs and charts
Candidates should be able to:

- present data in the form of charts, graphs, drawings or mixture of methods of presentation;
- select the most appropriate form of presentation for the data collected or provided, e.g. bar chart, histogram and line graph;
- select which variable(s) to plot and plot appropriately on clearly labelled x- and y-axes;
- plot all points or bars to an appropriate accuracy;
- follow the Society of Biology recommendations for putting lines on graphs.

Generally, candidates are expected to present data in the form in which the key points of the data can be most easily visualised:

- for quantitative data, this is likely to be a graph;
- for qualitative data this may be a table.

Candidates should:

- choose scales for the graph axes that allow the graph to be read easily, such as 1, 2 or 5 units to a 20 mm square;
- make the best use of the space available, using over half of the length and width of the grid;
- use pencil for lines on graphs.

The accepted scientific conventions for labelling the axes of a graph are the same as for the column headings in a table of results with both the quantity and the unit shown (where appropriate). Points should be finely drawn with a sharp pencil, but must still be visible. A fine cross or an encircled dot is suitable; a thick pencil blob is not. Often it is obvious that the data fall on a straight line or smooth curve, when a line of best fit or appropriate curve should be placed on the graph. Sometimes it is not possible to be sure if the line should be straight or a smooth curve, so adjacent points should be joined by straight ruled lines in order to represent the data with the minimum of assumptions. Lines of best fit should show an even distribution of points on either side of the line along its whole length. Lines should be finely drawn and should not contain kinks or breaks. If error bars are placed onto graphs, then the line of best fit must go through those error bars.

Analysis of data and conclusions

Display of calculation and reasoning
Candidates should be able to:

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

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

Calculated quantities should be given to the same number of significant figures as the measured quantity that has the smallest number of significant figures. For example, if values of time and of volume of gas collected are measured to 1 and 2 significant figures respectively, then the calculated rate should be given to 1 significant figure, but not 2 or more.

See **www.chemsoc.org/networks/learnnet/RSCmeasurements.htm** for more information on significant figures.

Description of patterns and trends
Candidates should be able to:

- use tables and graphs to draw attention to the key points in quantitative data, including the variability of data;
- describe the patterns and trends shown by data in tables and graphs;
- describe and summarise the key points of a set of observations.

Descriptions of patterns and trends should be precise, giving quotations of figures to support the description, and calculated values where these are appropriate.

Interpretation of data and observations
Candidates should be able to:

- identify the calculations that are necessary to be able to draw conclusions from primary and/or secondary data;
- use descriptive statistics to enable simplification of data, assess its variability and determine the confidence in the validity of conclusions;
- use appropriate statistical tests to determine goodness of fit and the statistical differences between samples;
- find an unknown value by using co-ordinates or axis intercepts on a graph;

- calculate other quantities from data or from quantitative data related to their qualitative observations, or calculate the mean from replicate values, or make other appropriate calculations;
- determine the gradient of a straight-line graph or tangent to a curve.

Candidates should know how to choose and carry out calculations required for simplifying data and to make it comparable. These may involve determining the following:

- mean;
- median;
- mode;
- percentages;
- percentage gain or loss;
- rate of reaction;
- magnification and actual size.

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

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

Candidates should know how to put error bars on graphs which may be calculated using standard error.

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

- chi squared test;
- t-test.

They should also know how to use Spearman's rank and Pearson linear correlation to test for correlation. See the **Notes on the use of statistics in biology** on p.110–111.

Candidates may be expected to derive unknown values which might include concentrations where a calibration curve has been drawn. When a gradient is to be determined, the points on the line chosen for the calculation should be separated by at least half of the length of the line or tangent drawn.

Candidates should be encouraged to use spreadsheets to collate and analyse the data they collect in their own practical work or when analysing secondary data. This makes it possible to assess the variability of their data. For further information see: Biology statistics made simple using Excel
http://baettig-seipelt.net/pdf/excel.pdf

Making conclusions drawing on theoretical knowledge and understanding
Candidates should be able to:

- draw conclusions from an investigation or from interpretations of observations, data and calculated values, providing a detailed description of the key features of the observations, data and analyses, and considering whether experimental data support a given hypothesis or not;
- make detailed scientific explanations of the data and of their conclusions, drawing on the skills, knowledge and understanding that they have gained from their studies of the Cambridge Pre-U syllabus;
- make further predictions and ask informed and relevant questions.

Key points of the raw data, graphical representations of it and statistical test results should be given, including quoting of relevant figures, leading to a clear indication of the strength or weakness of any support for or against the hypothesis, or indeed, its proof or refutation. Conclusions may be expressed in terms of support for, or refutation of, hypotheses, or in terms of the straightforward deductions or inductions that, logically, can be made from the data, observations or results of calculations. Detailed scientific explanations form a part of such conclusions and therefore form a part of this higher-order practical skill assessment, in which the candidates will be expected to refer to knowledge and understanding gained in their theory part of the course in order to provide explanations of their practical conclusions, for example making detailed reference to changes in protein structure when interpreting the effect of pH on enzyme activity.

Evaluation of procedures and data

Identifying limitations and sources of error
Candidates should be able to:

- make criticisms of the experimental procedure;
- evaluate the effectiveness of control of variables and thus the confidence with which conclusions might be drawn;
- identify the most significant sources of error in an experiment;
- estimate, quantitatively, the uncertainty in quantitative measurements;
- express such uncertainty in a measurement as an actual or percentage error;
- show an understanding of the distinction between systematic errors and random errors;
- identify anomalous values in provided data and suggest appropriate means of dealing with such anomalies;
- within familiar contexts, suggest possible explanations for anomalous readings;
- identify the extent to which provided readings have been adequately replicated, and describe the adequacy of the range of data provided;
- use provided information to assess the extent to which selected variables have been effectively controlled;
- use these evaluations and provided information to make informed judgements on the confidence with which conclusions may be drawn.

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

Candidates should be used to looking at experiments and assessing the relative importance of errors in measurement or in making observations so that they can judge which sources of error are most important. Candidates should be familiar with simple means of estimating error, such as the errors intrinsic in measuring devices (see **www.Chemistry-react.org/go/Tutorial/Tutorial_4428.html)** or in the observer's ability to observe, or in experiments where limitations of the method introduce errors (e.g. heat loss when trying to assess the energy content of biological materials). They should be able to express these errors in standard forms such as length = 73 mm ± 1 mm, or temperature increase = 14 °C ± 4 °C.

Candidates should be able to suggest which of the sources of error described are likely to be systematic errors such as those resulting from thermometers that consistently read 1 °C above actual temperature, or candidates who read volumes to the wrong part of the meniscus, as well as those which are likely to be random errors due to variability of biological materials, or random variations in room temperature.

For key control variables, candidates should be able to give a realistic estimate or appraisal of how effectively the variable was controlled, for example, how closely the temperature was maintained the same across a number of samples, and from this, give an indication of the confidence that they would have in any conclusions drawn.

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

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

Suggesting improvements
Candidates should be able to:

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

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

Candidates' suggestions should be realistic, so that in principle they are achievable in practice. The suggestions may relate either to the apparatus used or described in the question, or to the experimental procedure or to the nature of the observations or the means used to make them. Candidates may include improvements that they would make, such as repeating readings. The suggested modifications may relate to sources of error identified by the candidate or to other sources of error.

When asked for modifications, extensions to answer new questions should not be given.

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

Laboratory equipment

The following is a list of basic materials and apparatus which would be expected for a Centre providing this qualification. However, the list is by no means exhaustive.

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

The following codes are used where relevant.

C = corrosive substance
F = highly flammable substance
H = harmful or irritating substance
O = oxidising substance
T = toxic substance
N = environmentally hazardous substances

General

Test-tubes and large test-tubes (boiling tubes) – some test-tubes should be heat resistant
Test-tube holders or similar means of holding tubes
Test-tube racks or similar in which to stand tubes
Bungs to fit test-tubes/boiling tubes
Specimen tubes with corks
A means of heating – Bunsen burners or similar
Thermometers
Measuring cylinders
Means of measuring small volumes, e.g. syringes (various sizes)
Teat pipettes
Beakers
Tripod stands and gauzes
Filter funnels and filter paper
Petri dishes (plastic) or similar small containers
White tiles or other suitable surface on which to cut
Glass slides and coverslips
Conical flasks
Clamp (retort) stands and bosses
Visking (dialysis) tubing
Capillary tubing
Soda glass tubing
Paper towelling or tissue
Cotton wool
Solid glass rods
Black paper/aluminium foil
Means of writing on glassware (water resistant markers)
Hand lenses (not less than x6, preferably x8)
Forceps
Scissors
Mounted needles
Cutting implement, e.g. solid-edged razor blade/knife/scalpel
Mortars and pestles
Safety spectacles or other suitable eye protection

Microscope and lamp/inbuilt illumination with high and low power objective lenses (1 each or 1 between 2)
Eyepiece graticules and stage micrometers
Bench lamp with flexible arm
Balance (to 0.1 g)
Water-baths or equivalent
Cork borers
Stopclock/timer showing seconds
Simple respirometer – can be 'homemade'
Pipe cleaners/other suitable aid to demonstrate mitosis and meiosis
Apparatus to measure rate and depth of breathing
Petri dishes, culture bottles, autoclave
Inoculating wires/bioloops
Haemocytometers
Tape for sealing dishes

Stocks of:
Iodine in potassium iodide solution
Benedict's solution
[**C**] – biuret reagent/potassium hydroxide and copper sulfate solution
[**F**] – ethanol (for fats test)
[**F**] – methylated spirit (extraction of chlorophyll)
Sucrose (use AR for non-reducing sugar test)
Glucose
Starch
[**C**] – Potassium hydroxide
Sodium chloride
Dilute hydrochloric acid
Hydrogencarbonate indicator
Sodium bicarbonate/sodium hydrogencarbonate
Limewater
Distilled/deionised water
Universal Indicator paper and chart
Litmus paper
Neutral red solution or powder
Eosin/red ink
Methylene blue
Vaseline/petroleum jelly (or similar)
DCPIP (dichlorophenol-indophenol)
Ascorbic acid (vitamin C)
[**H**] – 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. copper sulfate)
Stains for preparing slides to show mitosis – e.g. carmine acetic, toluidine blue
[**H**] – Feulgen stain (Schiff's reagent)
[**H**] – 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 – see, for example:
www-saps.plantsci.cam.ac.uk/worksheets/scotland/lac.htm
Reagents, materials and apparatus required for investigations using DNA and electrophoresis – see, for example:
www-saps.plantsci.cam.ac.uk/worksheets/scotland/dna.htm
Appropriate disinfectants

Apparatus for sampling, e.g. 'open' and 'grid' quadrats, point quadrats
Apparatus for measuring abiotic factors, e.g. oxygen meter, flow 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
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 to use for temporary mounts
Examples of organisms representing the other three Kingdoms; 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
ts leaf of a CAM plant, e.g. Crassula

Microscale

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

Safety in the laboratory

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

Associations

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

Websites

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

Publications

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 Manual, SSERC, 1997
Hazardous Chemicals. An interactive manual for science education, SSERC, 2002 (CD)

UK Regulations

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

Appendix 2: Textbooks and IT Resources

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

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

Biozone Modular Workbook Series (Biozone International Ltd., **www.biozone.co.uk**)

Bradfield, P, Dodds, J, Dodds, J and Taylor, N (2001, 2002) AS Biology, A2 Biology (Pearson Education Ltd., **www.longman.co.uk**) ISBN 0582429463, 0582429455

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

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

*Campbell, N and Reece, J. (2009) Biology with Mastering Biology: International Version (8th Ed) (Pearson Educational, **http://vig.pearsoned.co.uk**) ISBN 978-0321623539

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

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

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

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

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

Jones, M, Fosbery, R, Taylor, D, Gregory, J (2007) CIE Biology AS and A Level (2nd ed. Cambridge University Press, **www.cambridge.org**) ISBN 978-052170306 2

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

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

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

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

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

Nicholl, D S T (2002) An Introduction to Genetic Engineering (2nd ed) Studies in Biology
(Cambridge University Press, **www.cambridge.org**) ISBN 0521004713
Phillips, W D and Chilton, T J (1994) A-Level Biology (revised ed)
(Oxford University Press, **www.oup.co.uk**) ISBN 0199145849
Ratledge, C and Kristiansen, B (2006) Basic Biotechnology (3rd ed)
(Cambridge University Press **www.cambridge.org**) ISBN 0521549582
Raven, P,H and Johnson, G.B. (2010) Biology (9th ed) (McGraw-Hill Higher Education, **http://catalogs.mhhe.com/mhhe/home.do**) ISBN 978-0071222068
*Roberts, M, Monger, G and Reiss, M (2000) Advanced Biology
(Nelson Thornes, **www.nelsonthornes.com**) ISBN 0174387326

Spicer, J (2006) Biodiversity, A Beginner's Guide
(Oneworld Publications) ISBN 1851684719
*Taylor, D J, Green, N P O, Stout, G W and Soper, R (1997) Biological Science 1 and 2 (3rd ed) (Cambridge University Press, **www.cambridge.org**) ISBN 0521561787

Taylor, J (2001) Microorganisms and Biotechnology (2nd ed) Bath Advanced Science
(Nelson Thornes, **www.nelsonthornes.com**) ISBN 0174482558
Taylor, D (2001) Growth, Development and Reproduction (2nd ed) Cambridge Advanced Sciences (Cambridge University Press, **www.cambridge.org**) ISBN 0521787211
Vardy, P (1999) The Puzzle of Ethics
(Fount) ISBN 0006281443

Biology Practical Skills books

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

Adds, J, Larkcom, E, Miller, R and Sutton, R (2001) Tools, Techniques and Assessment in Biology (Nelson Thornes Ltd) ISBN 0174482736
Cadogan, A and Ingram, M (2002) Maths for Advanced Biology.
(Nelson Thornes, **www.nelsonthornes.com**) ISBN: 0-7487-6506-9

Indge, B (2003) Data and Data Handling for AS Level
(Hodder Murray, **www.hoddereducation.co.uk**) ISBN 0340856475
King, T, Reiss, M and Roberts, M (2001) Practical Advanced Biology
(Nelson Thornes) ISBN 0174483082
Morgan, S (2002) Practical Work for Biology
(Hodder & Stoughton, **www.hodderheadline.co.uk**) ISBN 0340847123
Siddiqui, S A (1999) Comprehensive Practical Biology for A Levels
(Ferozsons, Lahore) ISBN 9690015729

Teachers may also find the following useful:

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

Stevens, A and Lowe, J (2004) Human Histology 3rd edition
(Mosby. **www.studentconsult.com/bookshop**) ISBN 0323036635

Cutler, DF, Botha, T and Stevenson, DW. (2008) Plant Anatomy.
(Blackwells. **www.blackwell.co.uk**) ISBN 9781405126793

Rockett, B and Sutton, R (1996) Chemistry for Biologists at Advanced Level
(John Murray) ISBN 0719571464

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

Meatyard, B (editor) (2009) Biological Nomenclature: Standard terms and expressions used in the teaching of Biology (4th Ed) (Society of Biology **www.societyofbiology.org**) ISBN 978-0-900490-39-2

CD-ROM

BIOSCOPE biological microscope simulation (Edition 2004)
Includes 56 slide sets of plant and animal specimens, with features that give the feeling of a real microscope. Paper-based tasks (in Word and PDF format), each of 45 to 60 minutes duration, accompany the slides. The slide set and tasks meet the needs of the Cambridge Pre-U Biology syllabus.
(Cambridge-Hitachi **www.cambridge-hitachi.com**) ISBN 1845650263

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

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

Biofactsheets
Published by Curriculum Press **www.curriculum-press.co.uk**

Teachers may find reference to the following websites helpful.

Kimball's Biology
http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/
Online Biology textbook written at a level above A Level, but suitable for providing accurate information on many of the topics in the syllabus.

John Kyrk's cell biology animations
www.johnkyrk.com
Superb animations of many topics in cell biology.

Practical Biology

School Science lessons – Biology
www.uq.edu.au/_School_Science_Lessons/UNBiology1.html

Science and Plants for Schools
www-saps.plantsci.cam.ac.uk

Don Mackean's website
www.biology-resources.com/biology-experiments2.html

Practical Biology
www.practicalbiology.org
A useful source of practical procedures for use at A level.

National Centre for Biotechnology Education
www.ncbe.reading.ac.uk
Source of information, kits and supplies for biotechnology. biochemistry and enzymology.

Microscopy and Histology

Royal Microscopical Society
www.rms.org.uk/index.shtml

Statistics and Analysis and Evaluation

Merlin
Merlin is a 'stats package' that is an add-in to Excel. It can be downloaded from:
www.heckgrammar.co.uk/index.php?p=10310

Percentage errors
For a useful tutorial on percentage errors for evaluating, see:
www.chemistry-react.org/go/Tutorial/Tutorial_4428.html

Simulations and tutorials

The Biology Place
www.phschool.com/science/biology_place/index.html

The Biology Project
www.biology.arizona.edu

Biology Labs On-line
www.biologylab.awlonline.com (1-day free trial available)

Tutorial for using RasMol (Molecular Modelling Software)
www.heckgrammar.co.uk/index.php?p=10311

Appendix 3: Mathematical Requirements

Candidates should be able to:

- recognise and use expressions in decimal and standard form
- use a calculator for addition, subtraction, multiplication and division, finding the arithmetical mean and to find and use x^2, $\frac{1}{x}$, $\sqrt{x}$,$\log_{10}x$
- take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified
- make estimations of the results of calculations (without using a calculator)
- recognise and use ratios
- correctly calculate percentages and express changes or errors as percentages and vice versa
- comprehend and use the symbols $<,>,\Delta,\approx,/,\propto,\Sigma$
- calculate areas of right-angled and isosceles triangles, circumference and area of circles, areas and volumes of rectangular blocks and cylinders
- translate information between graphical, numerical, and algebraic forms
- construct and interpret frequency tables and diagrams, pie charts and histograms
- select appropriate variables and scales for graph plotting using standard 2mm square graph paper
- for linear graphs, calculate the rate of change
- recognise when it is appropriate to join the points with straight 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 best line through a set of data points presented graphically
- understand, draw and use the slope of a tangent to a curve as a means to obtain the rate of change
- understand and use the prefixes: giga (G), mega (M), kilo (k), micro (μ), and nano (n)
- have sufficient understanding of probability to understand genetic ratios
- understand the principles of sampling as applied to biological situations and data
- understand the importance of chance when interpreting data
- use a spreadsheet program for collating, analysing and presenting data
- calculate standard deviation and standard error
- understand the benefits of using standard error and 95% confidence intervals (95%CI) to make statements about data and to use as error bars on graphs
- understand the difference between correlation and causation; use Spearman's rank and Pearson linear correlation to test for correlation
- use the χ^2 test and the t-test

Notes on the use of statistics in biology

Candidates should know about 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% CI. Standard error and 95% CI are useful for expressing the reliability of an estimate of the mean and for putting error bars on graphs. They 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 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. They 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. These statistical methods are dealt with fully in many books and web sites on statistics for Biology.

Candidates are **not** expected to remember the following equations and symbols. They **are** expected to be able to use the equations to calculate standard deviations 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. In both the t-test and the chi-squared test they should be able to calculate the number of degrees of freedom without any reminders. They should appreciate levels of significance and use calculated (or given) values of t and χ^2 to make appropriate conclusions.

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

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

t-test $t = \frac{\left|\bar{x}^1 - \bar{x}^2\right|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$ $v = n_1 + n_2 - 2$

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

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 should note that, on some calculators, the symbol σ may appear instead of the symbol s. Candidates are not expected to appreciate the difference between $s_n(\sigma_n)$ and $s_{n-1}(\sigma_{n-1})$. χ^2 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 Components 1, 2 and 3. The use of a spreadsheet to collate, analyse and present data from an individual or group study could form part of the Optional Formative Assessment.

Electronic calculators will be allowed in the examination, subject to the University of Cambridge International Examinations' general regulations.

Appendix 4: Some Suppliers

General

Scientific & Chemical Supplies Ltd., Carlton House, Livingstone Road, Bilston, West Midlands, WW14 0QZ.
Tel 01902 402402. Fax 01902 402343.
email: scs@scichem.co.uk ; website: **www.scichem.co.uk**

Philip Harris Education, Findel Education Ltd., Hyde Buildings, Ashton Road, Hyde, Cheshire. K14 4SH. Tel 0845 120 4520; Fax 0800 138 8881;
email: **sales@philipharris.co.uk**; website: **www.philipharris.co.uk**

Edu-Lab, Karoo Close, Bexwell Business Park, Bexwell, Norfolk PE38 9GA.
Tel 01366 385777 Fax 01366 386535;
email: **enquiries@edulab.co.uk**; website: **www.edulab.co.uk**

Griffin Education. Tel: 01509 233344; Fax: 01509 555200.
email: **griffin@fisher.co.uk**; website: **www.griffineducation.co.uk**

Timstar Laboratory Suppliers Ltd., Timstar House, Marshfield Bank, Crewe, Cheshire, CW2 8UY. Tel 01270 250459. Fax 01270 250601.
email: **sales@timstar.co.uk**; website: **www.timstar.co.uk**. Catalogue available on CD. This can be requested via their website.

Biotechnology kits and enzymes

National Centre for Biotechnology Education, School of Food Biosciences, The University of Reading, Whiteknights, PO Box 226. Reading. RG6 6AP.
Tel 0118 9873 743; Fax 0118 9750 140.
email: **NCBE@reading.ac.uk**; website: **www.ncbe.reading.ac.uk**

Edvotek, Europe Ltd., PO Box 280; Hertford, Hertfordshire, SG13 9DG, UK
Tel 01992 410140; Fax 01992 410106
email: **EUinfo@edvotek.com**; website: **http://edvotek.co.uk**

Bio-Rad
Freephone: 0800 181134; Tel 0208 328 2000; Fax 0208 328 2550
email: **uk_orders@bio-rad.com**; website: **www.bio-rad.com**

Chemicals

BDH / VWR International Ltd., Merck House, Poole, Dorset. BH15 1TD.
TTel 01202 660444; Fax 01202 666856.
website: **www.bdh.com**

Sigma-Alldrich. Tel 0800 717181.
email: **ukcustsv@sial.com**; website: **www.sigmaaldrich.com/united-kingdom/ordering.html**

Organisms
Blades Biological, Cowden, Edenbridge, Kent, TN8 7DX.
Tel 01342 850242; Fax: 01342 850924
email: **info@blades-bio.co.uk;** website: **www.blades-bio.co.uk**

Sciento, 61 Bury Old Road, Whitefield, Manchester, M45 6TB.
Tel 0161 773 6338; Fax 0161 773 6338
email: **sales@sciento.co.uk**; website: **www.sciento.co.uk**

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

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