Cambridge Assessment

A Level

Biology

Session: 1994
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University of Cambridge
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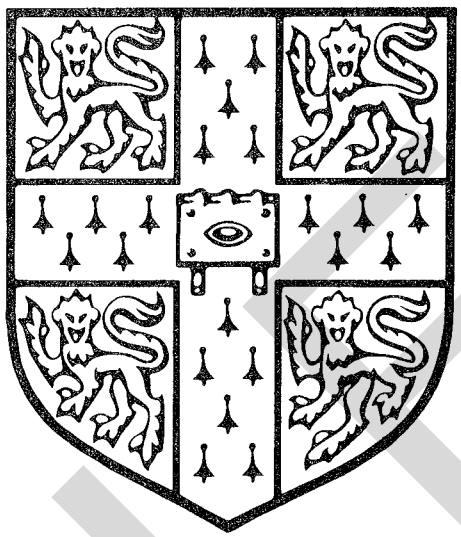

BIOLOGICAL SCIENCES

Examination Syllabuses for 1994 and 1995
(UK Centres only)

NOTES

Black lines in the margins indicate that changes have occurred as a result of revision.

1. **Nomenclature.** The recommendations on terms, units and symbols in *Biological Nomenclature* (1989) published by the Institute of Biology, in conjunction with the ASE, will generally be adopted. Reference should also be made to the joint statement on chemical nomenclature issued by the GCE boards. In particular, the traditional names sulphate, sulphite, nitrate, nitrite, sulphurous and nitrous acids will be used in question papers.

   It is intended that, in order to avoid difficulties arising out of the use of l as the symbol for litre, use of dm^3 in place of l or litre will be made.

2. **Functions of the syllabuses.** These syllabuses are designed to indicate topic areas and approximate depth of content, appropriate to level, that will be covered by examination questions. They are **not** intended to prescribe:
   (*a*) what teachers *must* teach,
   or, (*b*) to what depth a topic *must* be taught,
   or, (*c*) the order in which topics *must* be taught.
   It is for individual teachers, departments and Headteachers to decide teaching content, process and practice.

   Syllabuses are constantly under review and will be amended to provide increased guidance to teachers.

3. **Units, significant figures.** Candidates should be aware that misuse of units and/or significant figures, i.e. failure to quote units where necessary, the inclusion of units in quantities defined as ratios or quoting answers to an inappropriate number of significant figures, is liable to be penalised.

4. **Calculators** may be used in all components of these examinations provided the relevant regulations in the current version of "UCLES Handbook for Centres" are met.

5. **Cruelty to Animals**
   It must be stressed that no procedure should be carried out which causes any form of distress or pain to living organisms. With regard to any doubts or queries raised by the Cruelty to Animals Act (1876), the Home Office have drawn notice to *Biology Teaching in Schools Involving Experiment or Demonstration with Animals or with Pupils* by J. J. Bryant (An Association for Science Education publication).

Practical Work

The science syllabuses contained in this pamphlet have been prepared on the assumption that the courses will be based on practical work.

BIOLOGY
9260
GCE ADVANCED LEVEL

This subject may **not** *be taken with A Level Social Biology, or AS Biology (but see below).*

INTRODUCTION

The syllabus has been designed to aid the transition from GCSE to A level. Candidates will be assumed to have a knowledge of biology to GCSE level, as a single subject or as part of a balanced Science course.

The factual content of the traditional syllabus is reduced and the syllabus has been arranged in the form of Core content, to be studied by all candidates, and Options, of which three will be studied at A level. The Core is very similar to that for A level Social Biology, but most of the Options are different.

The syllabus places greater emphasis on the applications of Biology and the impact of modern developments on the needs of contemporary society. It is intended to keep the syllabus under frequent review, to ensure that it keeps abreast of knowledge in the biological sciences and of other needs.

Links with Advanced Supplementary Biology

The syllabus incorporates all of the Core material and some of the Options to be found in the Advanced Supplementary Syllabus. This link should allow teachers and candidates flexibility in the teaching of AS and A level courses. The syllabus also conforms to the Common Core required by the GCE Boards.

Two possible methods of combination with AS are:

1. Both AS and A level students follow the AS course for the first year and the remainder of the A level syllabus is completed in the second year by those wishing to take A level.
2. Since AS is intended to be a two year course, it can be taught for half of the A level teaching time each week to both A and AS candidates. The A level students study the additional syllabus content during the other half of the teaching time each week.

It must be stressed that these combinations are only examples of several ways in which the two courses, AS and A, might be combined in a common teaching group.

Advanced Supplementary Biology cannot be taken in the same examination session as A level Biology.

Links with Social Biology (9265)

The Core syllabus for Biology and Social Biology is very similar, allowing A level candidates for both subjects to be taught together. Some of the Options are common to both subjects; others are shared with AS. These links allow considerable flexibility in the teaching of the courses (see preceding paragraph).

AIMS

The syllabus aims to:

(a) develop an understanding of biological facts and principles and an appreciation of their significance,

(b) emphasise the social and applied aspects of Biology,

(c) encourage an awareness of the contribution of Biology to the needs of society,

(d) develop an understanding of the scientific method and its application,

(e) be complete in itself and perform a useful educational function for students not intending to study Biology at a higher level,

(f) be a suitable preparation for university and polytechnic courses in Biology, Biological studies in other educational establishments and for professional courses which require students to have a knowledge of Biology when admitted,

(g) encourage respect for all forms of life.

ASSESSMENT OBJECTIVES (and their weightings within the scheme of assessment)

The scheme of assessment will test:

(a) knowledge with understanding of biological facts, (35%)

(b) an awareness of the social, technological and environmental implications of Biology, (10%)

(c) the application of biological knowledge to
  (i) evaluating, drawing conclusions and making inferences from data,
  (ii) communicating scientific information in a variety of forms, including continuous prose,

(iii) solving problems, including some of a quantitative nature,
(iv) the discussion of problems faced by contemporary society, (30%)

(d) the ability to:
(i) **A** use and organise procedures, apparatus and materials,
B make and record observations and measurements,
C interpret and draw conclusions from experimental observations and data, (20%)
(ii) design investigations, evaluate them and suggest modifications. (5%)

SUMMARY OF WEIGHTINGS OF ASSESSMENT OBJECTIVES AND OF PAPERS

Paper nos.	*Paper weighting*	*Paper marks*	*Assessment Objectives*									
			a	*b*	*c*				*d*(i)			*d*(ii)
					(i)	(ii)	(iii)	(iv)	**A**	**B**	**C**	
1	15%	40	+	+	+		+					
2	25%	70	+	+	+	+	+					
3	30%	100	+	+	+	+	+	+				
4	10%	30	+		+	+						+
*5	20%	60							+	+	+	
*9	20%	60							+	+	+	
					12	8	8	2	6	6	8	
	100%	300	35%	10%	30%				20%			5%

*Alternative papers.

ADDITIONAL INFORMATION

Modern Biological Sciences draw extensively on concepts from the physical sciences. It is desirable therefore, that by the end of the course candidates should have a knowledge of the following topics, sufficient to aid understanding of biological systems, but no questions will be set directly on them.

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

Questions set in the examination may involve the basic processes of mathematics, for the calculation and use of decimals, means, ratios and percentages.

Candidates may be required to (i) construct graphs or present data in other suitable graphical forms, (ii) calculate rates of processes.

Candidates should be aware of the problems of drawing conclusions from limited data and should appreciate levels of significance, standard deviation and probability, and the use of t- and chi-squared tests, (see page 21).

SCHEME OF ASSESSMENT

(Papers 1, 2, 3, 4 and **one** *of 5 or 9 are compulsory: Paper 0 is optional)*

Paper	*Description*	*Duration*	*Marks*	*Weighting*
1	Multiple Choice	1 h	40	15%
2	Short answer questions and a free-response question	1½ h	70	25%
3	Structured questions (may include data response and comprehension) and free-response questions	2½ h	100	30%
4	Investigative assignment	—	30	10%
5	Practical examination	2½ h	60	20%
9	Teacher-assessed practical	—	60	20%

Papers 1 and 2 will be timetabled together.

Paper 1 (1h, 40 marks)

Forty multiple choice questions based on the Core syllabus. All questions will be of the direct choice type with four options. This paper will test Objectives (*a*), (*b*), and (*c*), (i) and (iii).

Paper 2 (1½h, 70 marks)

This paper will consist of two sections and will be based solely on Core topics. Section A will be a variety of short-answer questions which will be compulsory. Section B will contain three free-response questions from which candidates will choose one. The paper will test Objectives (*a*), (*b*) and (*c*) (i)-(iii).

Paper 3 (2½h, 100 marks)

Questions will be set on each of the Options shown in List A, but a knowledge of Core material may be required. The questions will test Objectives (*a*), (*b*) and (*c*) (i)-(iv). Candidates will be required to answer three questions on each of **two** Options from List A.

Questions 1 and 2 (about 40 minutes) will be compulsory structured/data-response/comprehension-type questions and will test Objectives (*a*), (*b*) and (*c*) (i)-(iv).

Question 3 (about 35 minutes) will be presented in an either/or form and will be a free-response question testing, in particular, Objectives (*b*) and (*c*) (ii) and (iv).

Paper 4 (based on 30-35 hours lesson time and representing 15-20 hours practical work, 30 marks)

An investigative assignment based on one of the Options shown in List B. The submission should be an individual study based on a practical investigation of a topic from the chosen Option. Successful assignments will be those based on a clearly defined hypothesis. The assignment should show evidence of the candidate's ability to put forward an hypothesis, to design an investigation, to conduct appropriate practical work, to collect and analyse data and to present reasoned arguments in evaluation of the data and in suggesting modifications to the original design. A Teachers' Handbook will be available in Autumn 1992.

The investigative assignment will be assessed by UCLES and will test Objectives *(a), (c)* (i) and (ii) and, in particular, *(d)* (ii).

Centres following the syllabus for the first time should notify the Subject officer at the beginning of the academic year in which they intend to start teaching, since it would be advisable for titles and brief descriptions of the proposed assignments to be sent for approval to UCLES. Outline Proposal Forms should be completed well before the work is begun, and not later than 1 November in the year preceding the examination.

The investigative assignment should be between 1500 and 2000 words, (excluding headings, tables and appendices), and should be based on 15-20 hours practical work.

Centres will receive the name and address of their examiner in April in the year of the examination and should send all candidates' investigative assignments to that address **by 30 April at the latest.** Teachers will be invited to estimate the quality of their candidates' assignments on a 5-point subjective scale.

Pages must be numbered and the assignments should be submitted in light paper folders and **not** in heavy ring binders.

(See page 29 and the General Information on the teaching of List B Options, page 21).

Paper 5 (Alternative to Paper 9) (2½h, 60 marks)

This paper will be a practical examination which is set and marked by UCLES. Each paper may include experiments and investigations based mainly on the Core syllabus. Where unfamiliar materials/techniques are required, full instructions will be given. Observations may be made using a microscope and/or hand lens. Questions involving an understanding of the use of t- and chi-squared tests may be set, but detailed computation of these tests will not be required in the examination.

Although no dissection will be set in this paper, dissection will continue to be a useful aid to teaching e.g. when the heart is being studied.

Candidates will be expected to show evidence of the following skills (Objective *(d)* (i)) in the handling of familiar and unfamiliar biological material:

A Using and organising procedures, apparatus and materials,

B Observing, measuring and recording,

C Interpreting experimental observations and data.

Paper 9 (Alternative to Paper 5) (60 marks)

Teacher assessment of practical skills. This is intended to reflect practical work carried out throughout the course, and will test the same skills as Paper 5 (see above). Further information is given on page 30. (Not available in the November examination, but see note below concerning Paper 89.) A Teachers' Handbook is available.

Special Paper (Paper 0) (2½h)

This paper (available in June only) is optional and requires a special fee. It is designed to give opportunities for candidates to show their ability to think independently and to give evidence of wide reading. The paper will consist of **seven** questions of which three questions will be based on the Core syllabus and each of four questions will be biased towards a different List A Option. Candidates must answer **any three** questions. The paper will often contain questions of a rather general nature which will require candidates to select and organise the most appropriate arguments and/or pieces of information with which to illustrate their arguments.

Paper 84

This paper applies to candidates who have taken the June examination and will carry forward their Paper 4 mark to the November examination. The term *Paper 84* is used for administrative purposes only.

Paper 85

This paper applies to candidates who have taken the June examination and who have elected to carry forward their June practical performance to the November examination. The term *Paper 85* is used for administrative purposes only.

Paper 89

This paper applies to candidates who have taken the June examination and who have elected to carry forward their Paper 9 mark to the November examination. The term *Paper 89* is used for administrative purposes only.

STRUCTURE OF SYLLABUS

The syllabus is divided into two parts:

1. The Core syllabus — to be studied by all candidates and to take up to 137 hours of teaching time.

   There are six Core components:

   A Cellular Activities,
   B Genetic Control and Inheritance,
   C Reproduction, Inherited change and Evolution,
   D Energetics,
   E Ecology,
   F Regulation and Control.

2. The Options — candidates will study and be assessed on **three** of the options, **two** from list A and **one** from list B.

   Each option in list A is to take up to 35 hours of teaching time.

LIST A	LIST B
1. Diversity of Organisms	5. Animal Behaviour
2. Applied Plant Science	6. Conservation
3. Applications of Genetics	7. Microbiology and Biotechnology
4. Growth, Development and Reproduction	8. Aspects of Heterotrophic Nutrition

Options from List A will be assessed by means of a written examination.

Options from List B will be assessed **only** by means of an investigative assignment.

The options in List B provide an opportunity for students to explore an area of Biology in more detail. These options will be assessed by means of an investigative assignment. This should be seen as a natural progression from the planning of investigations which was one of the GCSE experimental skills.

The extent to which the List B options should be taught, will depend largely on the nature of the assignments chosen by the students and the discretion of the teacher(s) involved. (For the purposes of the assignment, a wide interpretation of option content will be acceptable. It is expected that between 30-35 hours should be allowed for the options in List B.)

It is not necessary for all the students in one Centre to choose the same option for an investigative assignment unless they wish to do so.

The syllabus is based on a total of 260 hours, with 240 hours used for teaching the Core and Options, and 20 hours available for the investigative assignment, further practical work, or for practical assessment.

SUBJECT CONTENT

The syllabus content for the Core and List A Options is presented in two columns. The left hand column gives a limited number of key concepts. The examination will assess the candidate's knowledge and understanding of these. The notes in the right hand column are intended as amplification and suggest ways in which the key concepts may be taught. Questions may be set both on the concepts stated in the left hand column and on the specific topics listed in the right hand column.

It is expected that practical activities will underpin the teaching of the whole syllabus. The sections in *italics* in the Core and List A Options are thought to lend themselves particularly to practical studies, but it is expected that other practical work will be done.

Suggestions are given for the approximate teaching time to be devoted to each syllabus section, based on a total of 260 hours.

CORE SYLLABUS (*137 hours*)

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

Concepts	*Amplification*
A CELLULAR ACTIVITIES (35 hours)	
(a) The cell as the fundamental unit of living organisms with the ability to carry out life processes	Characteristic features of all eukaryotic cells.
	Structure of generalised plant and animal cells with emphasis on fundamental differences between them.
(b) Sub-cellular organisation	*Structure* and function *of membranes and principal organelles of plant and animal cells, including the nucleus.*
	Basic molecular structure of membranes; fluid mosaic model.
	Plant and animal cells as seen in the electron microscope, including an outline of the methods of preparation and of the principles of electron microscopy and its limitations. (The unit relevant here and in relation to wavelengths, molecular size, membranes, organelles and viruses is the nanometre (nm), 10^{-9} metres.)
	A review of the structure and function of the principal membranous organelles with single or with double membranes (envelopes), and their size and distribution within the cell: tonoplast, endoplasmic reticulum, Golgi apparatus, lysosomes, chloroplasts and mitochondria. The function of the lysosome and its relation to the Golgi apparatus. The inter-relationship of endoplasmic reticulum and Golgi apparatus.
	The structure of the nucleus in terms of nuclear envelope, nucleolus, chromatin and chromosomes.
(c) All cells have a similar chemical composition comprising	The structure and roles of carbohydrates, lipids, proteins, ions and water.
(i) carbohydrates	General formula of carbohydrates. The structure of monosaccharides in outline, including ring structures of pentoses and hexoses. Hexoses as the units from which other important carbohydrates are formed by condensation reactions.
	The glycosidic bond, disaccharides and polysaccharides. *The use of Benedict's solution in testing for the presence of reducing sugars and, after acid hydrolysis, of non-reducing sugars; iodine/potassium iodide solution for starch.*
	The many properties and roles of the different types of carbohydrates in living organisms, emphasising their importance in plant structure, energy relations and as constituents of complex macromolecules e.g. DNA, ATP.
(ii) lipids	The solubility of lipids. The basic structure of fats and oils. *The use of the ethanol emulsion test in*

	testing for the presence of fat and oil. The structure of a typical phospholipid. The roles of lipids in living organisms, emphasising the importance of phospholipids in membrane structure.
(iii) proteins	The amino acid as the fundamental unit from which proteins are formed by condensation reactions. Amino and carboxyl groups. The variety of α-amino acids. Dipeptides and polypeptides, including reference to the peptide bond. The unlimited number of possible polypeptides.
	The use of the biuret test in testing for the presence of a peptide linkage.
	The amino acid sequence as the primary structure of proteins. The secondary and tertiary structures of proteins. The association of polypeptide units to form the quaternary structure.
	The binding of non-protein groups to form conjugated proteins. A consideration of the roles of proteins in living organisms, emphasising the differences between fibrous and globular proteins and the importance of the shape of a protein for its functions. Reference should be made to the role of proteins as antigens and antibodies and their function as buffers.
	The factors resulting in denaturation and their significance.
(iv) inorganic ions	Reference should be made to the biological significance of inorganic ions as shown by the roles of calcium and iron.
(v) water	Water as a major constituent of active cells and therefore of living organisms.
	The hydrogen bond and the significance of the polarity of water to its physical and chemical properties. The roles of water in living organisms and as an environment for organisms.
(d) Metabolic activities are controlled by enzymes	The role of enzymes as biological catalysts. The protein nature of enzymes. The mode of action of enzyme and substrate, lowering of activation energy and enzyme specificity.
	The properties of enzymes *including a study of the influence of temperature, pH and substrate concentration on the rate of enzyme-mediated reactions.*
	Enzyme denaturation and inhibition: including end product inhibition, **one** example of a competitive inhibitor and **one** example of a non-competitive inhibitor.
(e) DNA is the genetic material	Evidence that DNA is the hereditary material.
(f) DNA is a double-stranded molecule capable of replication	The structure of DNA. The association of nucleic acids with the nucleus. The nucleotide as a condensation product of a pentose sugar, base and inorganic phosphate. The linking of nucleotides by condensation reactions to form a nucleic acid.
	The distinction between RNA and DNA nucleotides. The concept of base pairing including evidence for this. The 3-D structure of DNA.

	The semi-conservative mechanism of replication including unwinding and complementary nucleotide pairing.
(g) Mitosis is a process involving duplication of chromosomes and their equal division into two daughter cells	The exact duplication of chromosomes in interphase.
	The behaviour of chromosomes during the stages of nuclear division.
	The maintenance of the diploid condition and the constancy of the genetic information.

B GENETIC CONTROL AND INHERITANCE (15 hours)

(a) Information is coded in the base sequence of a single strand of DNA	The triplet genetic code.
(b) DNA is transcribed to mRNA and translated into specific sequences of amino acids	The role of mRNA, tRNA and ribosomes, in outline only. (**No** details of the structure of tRNA and ribosomes are required.)
(c) One gene carries the information to produce one polypeptide	Sickle cell anaemia as a medical condition illustrating the concept.
(d) Meiosis is a process involving duplication of chromosomes, two divisions of the nucleus and the formation of four haploid cells	Detailed knowledge of chromosomes behaviour during meiosis is **not** required. The following broad principles only should be covered.
	The exact duplication of chromosomes in interphase.
	Examination of bivalents. The exchange of genetic material between homologous chromatids.
	The separation of maternal and paternal homologues leading to independent assortment and genetic variation in gamete cells.
(e) Fertilisation produces new combinations of alleles	The uniqueness of the individual.
(f) Discontinuous and continuous variation is a characteristic of living organisms	Genotype and phenotype. The contribution of heredity and environment to the phenotype. The importance of discontinuously varying characters in the unravelling of the laws of heredity.
(g) Inheritance has a particulate nature	The law of segregation of factors. The independent assortment of factors, (X-ref. B*(d)*).
	The use of the term allele to describe each of the alternative factors responsible for a character difference.
(h) The expression of alleles influences phenotype	The frequency and appearance of dominant, codominant and recessive characters in monohybrid crosses. Crosses producing 3:1, 1:2:1, and 1:1 ratios.
	Dihybrid crosses producing 9:3:3:1 and 1:1:1:1 ratios, and the use of genetic diagrams to explain the results of crosses.
	Linkage and crossing-over, sex chromosomes, sex determination and sex linkage. The use of genetic diagrams for linked and sex-linked characters (including red-green colour blindness and haemophilia).

	Multiple alleles and codominance. Reference should be made to the inheritance of human ABO blood groups. Polygenic inheritance. The genetic explanation of continuous variation.

C REPRODUCTION, INHERITED CHANGE AND EVOLUTION (10 hours)

(a) Nuclear division is involved in the production of new individuals	Mitosis as the basis of asexual reproduction.
(b) Genes may mutate and the rate is increased by ionising radiation and some chemicals	The importance of gene mutation and its effects. Point (gene) mutation.
(c) Chromosome mutation produces a major change in the genome	Chromosomal mutations. Polyploidy. Down's syndrome.
(d) Gene and chromosome mutations contribute to evolutionary change	Variation in natural populations. Concept of the gene pool supplying the basis on which natural selection operates.
(e) Overproduction of offspring leads to differential survival and reproduction	Darwin's explanation of competition and survival and neo-Darwinian developments.
(f) Selection may cause changes in gene frequency	Principles of artificial and natural selection. (Detailed examples are **not** required.)

D ENERGETICS (32 hours)

(a) Cells require a controlled supply of energy and nutrients to function and survive	The uses of energy and nutrients in plants and animals.
(b) Light energy from the sun is converted to chemical energy in green plants	The structure of the chloroplast in relation to function. *The chromatographic separation of pigments from a green leaf extract.* The photoactivation of chlorophyll resulting in the conversion of light energy into the chemical energy of ATP and the reduction of NADP. (**No** biochemical detail required.)
(c) ATP and reduced NADP are used to convert carbon dioxide to carbohydrates	Carbon fixation and the subsequent series of energy-requiring enzyme-catalysed reactions leading to the formation of carbohydrates.
(i) by the C_3 pathway	An outline of the Calvin cycle, including reference to the use of ^{14}C-labelling techniques to identify intermediates. The light-independent fixation of CO_2 by combination with a 5C compound (RuBP) to yield two molecules of GP (PGA) (3C). The conversion of GP in the presence of ATP and reduced NADP into triose phosphate, some of which condenses to form hexose phosphates, sucrose and starch. The use of some of the carbohydrate to regenerate RuBP. The importance of GP in the formation of amino acids and lipids. (**No** other biochemical detail is required.)
(ii) by the C_4 pathway	Brief reference to the advantage of the combination of CO_2 and a 3C compound, phosphoenolpyruvate (PEP) to form a 4C organic acid prior to the Calvin cycle reactions. The physiological implications of the pathway should be mentioned: increased photosynthetic efficiency; ability to maintain this at higher light intensities and temperatures; the effect on the water relations of the plant.

(d) The concept of limiting factors	The concept of limiting factors as shown by the factors affecting the rate of photosynthesis.
(e) Carbohydrates and other organic compounds in plants are the initial energy sources for heterotrophs	Herbivores, carnivores, and omnivores convert complex carbohydrates and other organic compounds to simple soluble compounds for absorption into cells.
(f) Glucose is broken down to supply energy for metabolism in stages	The breakdown of glucose by a series of enzyme-catalysed reactions leading to the formation of ATP.
(i) glycolysis	A summary of the principal stages of the glycolytic pathway including reference to the yield of useful energy. The splitting of hexose phosphate (6C) into two triose phosphate (3C) molecules which are then further oxidised to pyruvate with a small yield of ATP and reduced NAD. (Oxidation and reduction in terms of the removal, or addition, of hydrogen atoms.) The role of dehydrogenases. Site of glycolysis in cells.
(ii) the Krebs cycle	An initial oxidative decarboxylation i.e. removal of CO_2 and oxidation by removal of hydrogen of pyruvate produces an acetyl group combined with coenzyme A as acetyl-CoA. The acetyl-CoA enters the Krebs cycle by combining with a 4C compound, the 6C compound so formed undergoing further oxidative decarboxylation with the release of more energy and reduced NAD. The role of decarboxylases. (**No** other biochemical detail is required.) Site of the Krebs cycle in cells. The importance of the Krebs cycle as a terminal oxidative pathway for fat and protein should be noted, together with the extent to which interconversion of lipid, carbohydrate and amino acids is possible via the Krebs cycle.
(iii) electron transport	The production of ATP from reduced NAD by oxidative phosphorylation.
(iv) anaerobic respiration	The production of a small yield of ATP from anaerobic glycolysis with the formation of ethanol in yeast and lactate in mammals. *Investigation of the effects of temperature on the rates of carbon dioxide production and oxygen uptake, using a respirometer.*
(g) ATP is the link in cellular energy transfer	Use of ATP in animals and plants for mechanical, electrical and chemical work and for heat production.
(h) The localisation of the respiration reactions in the mitochondrion	The structure of mitochondria. Their role in the different stages of respiration, with particular reference to the inner membrane and electron transport. (Oxidation and reduction in terms of electron transfer.) The role of ATP in the coupled reactions of intermediary metabolism.
(i) Muscular contraction is an example of work	An outline of the structure of striated muscle and the sequence of events by which muscular contraction and relaxation of striated muscle is brought about, including innervation and the neuromuscular junction. The rachet mechanism involving myosin and actin.

E ECOLOGY (10 hours)

(a) Recognition of different levels of ecological organisation	Definitions of species, habitat, niche, population, community and ecosystem.
(b) Recycling of nutrients	The importance of decomposers in the release of nutrients. The roles of bacteria and fungi in the carbon and nitrogen cycles (the scientific names of the bacteria are **not** required).
(c) Energy flows through the ecosystem in a linear fashion and is lost	Trophic levels, associated pyramids of energy and the relative efficiencies of energy flow. Food chains and food webs. *An ecosystem studied in relation to an area familiar to candidates.*

F REGULATION AND CONTROL (35 hours)

(a) The need to maintain a constant internal environment in cells and in all living things	The concept of homeostasis. The principles of control systems in cells and organisms. Homeostasis involves receptors, effectors, monitors and feed-back loops. The homeostatic functions of the liver. The role of the liver in carbohydrate metabolism and fat metabolism; storage of vitamins A, B, and D; synthesis of plasma proteins; breakdown of erythrocytes; detoxification and deamination of amino acids.
(b) In multicellular animals and plants, the need for	
(i) a gaseous exchange system	Gaseous exchange requires a large surface area. In large animals, a mass flow system consisting typically of a ventilation mechanism and a blood transport system. Structure of the mammalian gaseous exchange system. The importance of ventilation and the advantage of air as a respiratory medium; the mechanism and control of breathing, and the roles of mucus, cilia and nasal hairs. In plants, transport by diffusion. Movement in gaseous phase through stomata, moist intercellular spaces and, in aqueous phase, across moist cell walls.
(ii) a transport system	*Structure and function of arteries, veins, capillaries, xylem vessels, sieve tube elements and companion cells.* The blood system as a means of achieving a constant internal environment as well as integrating physiological processes. Role of haemoglobin in the transport of oxygen and carbon dioxide. Oxygen dissociation curves. Bohr effect. The role of myoglobin in the supply of oxygen for muscular contraction. Oxygen dissociation curves for myoglobin. The oxygen debt. *Structure of the heart.* The initiation of heart action. Cardiac cycle. Hormonal and nervous control of heart action. *Major components of blood* and their functions in transport only.

	Transpiration as an inevitable consequence of gaseous exchange in plants. Water loss through stomata.
	Translocation as the movement of assimilates, especially sucrose, between the leaves and other parts of the plant.
	TS of an herbaceous dicotyledon leaf and stem to show distribution of the tissues involved in transpiration and translocation.
(c) The need for compounds to enter cells	Differential permeability of the membrane. Pinocytosis, phagocytosis and osmosis.
	Diffusion and active uptake as illustrated by the active uptake of ions from soil solutions into root parenchyma cells, and of sodium ions from the proximal convoluted tubules of kidney nephrons.
	The movement of water between plant cells, and between them and their environment, should be understood in terms of water potential. In living plant cells, pressure potential is usually positive and the solute potential is always negative. (Calculations will **not** be set.)
(d) Control and co-ordination in mammals involves	
(i) the endocrine system	The nature of an endocrine gland, the location of the principal endocrine glands and mode of transport of hormones.
	The role of the pancreas, the thyroid gland and the adrenal gland in the regulation of metabolic activity.
	The functions of insulin, thyroxine and adrenaline.
	The concept of negative feedback in the control of hormone secretion.
	Reference should be made to the control of insulin secretion, and to the role of TRF from the hypothalamus and thyroid stimulating hormone (TSH) from the pituitary in the control of thyroxine secretion. (Pathological details of the result of imbalance are **not** required.)
(ii) the nervous system	The structure and function of sensory and motor neurones, and of the synapse.
	The reflex arc; **one** example to be studied.
	The generation and transmission of nerve impulses along the axon.
(e) Waste materials are produced by, and must be removed from, cells and organisms	The importance of removing nitrogenous and other compounds.
	The gross structure of the kidney. *Histology of the kidney.*
	The detailed structure of the nephron and associated blood vessels and their functions in the control of water, ions, pH and metabolic waste levels of the body fluids.

LIST A OPTIONS

OPTION 1 (35 hours)

DIVERSITY OF ORGANISMS

Introduction

Candidates should be encouraged to appreciate the wide diversity of organisms based on first-hand observation and to develop a due respect for living organisms and their environment. *Wherever possible, fieldwork should be carried out to study living examples of the organisms listed, in their natural habitats, to demonstrate aspects of their distribution and environmental adaptations.* Candidates will be expected to recognise the **external** features used in the identification of the major animal and plant taxa but **details** of internal anatomy are not required unless otherwise stated. In line with the Recommendations on Biological Nomenclature (Institute of Biology 1989) the terminology in this option should be based on Margulis and Schwarz (1988).

1. The varying complexity of organisms.	The consequences of the following should be considered as the phylogenetic sequence outlined in Section 2 is studied: increase in size and complexity; surface area to volume ratios; acellular and multicellular organisation and tissue and organ differentiation.
2. The variety of life.	Representative organisms from the following groups should be selected and candidates should be able to recognise the external features used to classify these organisms into the major group shown. For each group of organisms in the left-hand column, the points listed in the right-hand column should also be considered.
(a) Viruses	A brief review of their characteristics and mode of replication.
(b) Prokaryotae	Prokaryotic organisation shown by a bacterium.
(c) Fungi	Fungi as eukaryotes. One example of a saprotrophic fungus to illustrate general structure of a fungus.
(d) Protoctista	
(i) protozoans	Internal and external structure of a protozoan.
(ii) green algae	The general features of a unicellular **or** filamentous green alga.
(iii) brown algae	The general features of a thalloid brown alga.
(e) Plantae	
(i) bryophytes	An outline of the life cycle of a liverwort **or** moss as an example of a plant showing an alternation of generations.
(ii) ferns	An outline of the life cycle of a fern. The external features of both the gametophyte and sporophyte should be studied.
(iii) flowering plants (angiosperms)	Outline of the life cycle of an angiosperm, including a brief account of alternation of generations without structural details. The general features of an herbaceous dicotyledon.
(f) Animalia	
(i) cnidarians	The diploblastic structure of cnidarians; the tissue grade of organisation.
(ii) annelids	The generalised structure of a triploblastic coelomate. External features of an earthworm.
(iii) arthropods	Distinguishing characteristics of an insect. Life cycle of a named insect.

(iv) chordates	Characteristics and external features of one fish and one mammal, including those features, both external and internal, associated with locomotion and gaseous exchange.
3. Taxonomy.	
(a) The principles and purposes of classification	An appreciation of the function of a classification system.
(b) The concept of the species:	Problems in defining the species and using it as a fundamental unit in classification.
(i) nomenclature	The binomial system of Linnaeus.
(ii) natural classification	The hierarchy of taxa. The phylogenetic approach to taxonomy and its limitations.
(iii) artificial classification	*The construction and use of dichotomous keys.*

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In addition to standard textbooks and articles in the Scientific American, New Scientist and Biological Sciences Review, the following references may prove useful.

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British Museum (Natural History) Publication no.876. Classification, a beginner's guide to some of the systems of biological classification in use today (1983).

OPTION 2 (35 hours)
APPLIED PLANT SCIENCE

Introduction

The aim of this option is to illustrate the far-reaching effects of applied science in food production technology. Candidates should be encouraged to appreciate that Biology should be studied in relation to the needs of people. Analysis of the factors that contribute to plant growth and yield has enabled the limiting factors to be identified and productivity to be greatly increased. Agriculture and horticulture should therefore be considered in terms of applied ecology and physiology. Success in productivity has had considerable social, environmental and economic effects. These should be considered together and not in isolation.

1. Agriculture and horticulture are vital in the supply of food for Mankind.	Importance of climate and other factors in determining the type of food produced. Choice of food produced is determined by nutritional, environmental, cultural and economic factors. Problems of food surpluses should be considered. Food supply in developing countries and the implications of the Green Revolution.
2. Plant productivity and yield are influenced by various factors.	
(a) The structure of the leaf in relation to its photosynthetic function and water loss.	*The general distribution of the tissues in a dicotyledonous and a monocotyledonous leaf.* The structure and function of a stoma. Turgor changes leading to movement of the guard cells.

(b) The process of water transport and translocation.	*The structure of xylem and phloem* and the processes involved in the passage of water and assimilates through the stem and the leaf.
(c) Environmental limitations on the yield of field crops.	*Effect of light, temperature, water, carbon dioxide and nutrients on plant growth.*
(d) Plant growth under artificial conditions.	Greenhouse culture as a technological process involving the control of light, temperature, carbon dioxide and nutrient supply.
(e) Plant growth.	*Measurement. Outline of the role of auxins, gibberellic acid and abscisic acid on plant growth.* The use of plant growth regulators to improve plant performance.
(f) The various ways in which the term *productivity* can be defined and measured.	The meaning and relevance of the terms: *relative growth rate, leaf area index, net assimilation rate, biomass and harvestable dry matter.*
3. Factors affecting crop yield and quality.	The balance between yield and cost to be considered. Environmental impact of agricultural practices.
(a) Agricultural practices.	Ploughing, direct drilling, rotation of crops, harvesting methods, storage of crops.
(b) Use of fertilisers.	The need for significant inputs of nitrogen, phosphorus and potassium; the significance of these elements. The role of **two** trace elements in plant growth. Leaching of fertilisers from the soil leading to eutrophication and water pollution.
(c) Use of herbicides and insecticides.	The beneficial and harmful effects to be studied. Candidates should be encouraged to develop a balanced view of the use of these compounds. The importance of weed and pest control.
4. Plant productivity may be limited by disease.	Outline of the methods to control fungal diseases. The life cycle of a **named** fungal parasite and details of the methods for its control.
5. Plant productivity can be increased by the selective breeding of plants.	Need to maintain gene banks to conserve genetic variation. Aims of breeding programmes. **One** programme to be studied in detail.

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See also articles in Biological Sciences Review, Philip Allan Publishers Ltd.

Information on a rapid-cycling variety of *Brassica campestris* and its use in studying plant biology can be obtained from Science and Plants for Schools (SAPS) at Homerton College, Cambridge, CB2 2PH.

OPTION 3 (35 hours)

APPLICATIONS OF GENETICS

Introduction

Throughout this option the ethical and environmental implications should be considered.

1. Variation as a basis of selection

(a) Sexual reproduction leads to variation in the offspring (X-ref.–Core **C(d)**).	The concept of variance. Polygenes and the additive genetic component leading to continuous variation.
	Gene interaction at one locus (dominance) and between loci (epistasis).
(b) The environment can also lead to variation.	**Two** examples of the *effect of environment on phenotype*.
(c) Characteristics are passed from parent to offspring.	Measurement of heritable characteristics. Milk yield in cows, egg production in chickens. Any other examples.
	At least one practical investigation involving the recognition of phenotypic ratios in successive generations.

2. Selective breeding.

(a) The desirable characteristics of organisms can be selected by selective breeding.	Similarity of selective breeding to the evolutionary process. **Two** examples of changes in organisms brought about by selective breeding.
	Selection of traits in animals. Progeny testing. The harmful effects of in-breeding. The storage of sperm in sperm banks and use in artificial insemination, (A.I.). Advantages and disadvantages of A.I. Pedigrees. The use of, and techniques used in, embryo transplantation. Implications of the use of some of these methods in humans.
	Methods used to produce hybrids in plants. Methods to ensure that self-pollination does not occur.
(b) It is necessary to maintain a gene bank for possible future use.	Changes in the popularity of certain types of plant or animal. The trend from fat to lean animals. The need to conserve wild types and rare breeds as genetic resources.
(c) Selective breeding can be used to produce disease- and pest-resistant varieties.	Genetic basis of resistance. Method of producing disease-resistant varieties in plants, with actual examples.
	The development of antibiotic-resistant strains of bacteria. Development of disease resistance in animals. Resistance to pesticides.

(d) Plants can be modified by genetic engineering and then propagated by cloning from tissue cultures.	Techniques of genetic manipulation. Recombinant DNA. Hazards and possible benefits of this technique. Reference to actual examples such as change in the structure of storage protein in seeds.
3. Human genetics	
Many abnormal conditions have a genetic basis.	Cystic fibrosis, achondroplasia and galactosaemia as hereditary abnormalities. Genetic screening — its uses and consequences for moral decisions. Significance of genetic constitution for tissue compatibility in transplant surgery.

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Recent developments are well covered in New Scientist. See also articles in Biological Sciences Review. Information on kits for plant genetic engineering and tissue culture can be obtained from the educational suppliers Philip Harris Biological, Oldmixon, Weston-super-Mare, Avon, and Griffin and George, East Preston, West Sussex.

Information on a rapid-cycling variety of *Brassica campestris* and its use in studying plant genetics can be obtained from Science and Plants for Schools (SAPS) at Homerton College, Cambridge, CB2 2PH.

Schools should note any specific advice by the Local Education Authority on the use of microorganisms.

OPTION 4 (35 hours)

GROWTH, DEVELOPMENT AND REPRODUCTION

Introduction

Growth, development and reproduction are considered in the context of a range of organisms. Patterns and trends should be identified, together with the problems involved in measurement. An appreciation of hormonal control should form the basis for the understanding of this option.

1. *(a)* Growth is an irreversible increase in mass.	Cell enlargement and division as the basis of growth. The measurement and analysis of growth of microorganisms, plants and animals. Absolute and relative growth rates. Problems of measurement. Types of growth curve. Patterns of growth. *Measurement of growth, to include dry mass.*
(b) Development results in an increase in the level of complexity.	The concept of development as a progressive sequence of changes. The specialisation of cells.
2. Plants reproduce, develop and grow.	
(a) Vegetative propagation leads to genetic uniformity.	A brief survey of the principal natural methods of vegetative propagation, with reference to peren-

	nation and artificial methods of propagation. Genetic uniformity of propagules. *Two named examples, to include investigation of food reserves.* Commercial uses of vegetative propagation.
(b) Sexual reproduction requires specialised structures to allow for pollination.	The effects of daylength on the flowering process; control. The principal flower parts. Anthers and pollen formation. Ovule development. Reference should be made to insect and wind pollination, with consideration of structural and developmental features. A comparison of self and cross pollination and the subsequent outcome after fertilisation. *Living material should be studied where possible.* *Microscopic examination of floral reproductive structures.*
(c) Fertilisation produces new genetic combinations.	The fusion of haploid nuclei within the embryo sac, double fertilisation. The genetic diversity of the product.
(d) Changes occur after fertilisation leading to the development of the seed and fruit.	The development of the zygote within the ovule to form the embryo within the seed, and of the ovary to form the fruit. Origins of testa and pericarp. Seed structure. Physiological changes within seed and fruit. *Development of an embryo (e.g. Capsella).*
(e) Interacting factors influence germination.	The reason for, and the advantages of, dormancy. Interaction of hormones in the control of dormancy. Conditions needed for germination. Factors affecting germination. *Enzyme production by excised embryos.*
(f) Primary growth involves a change from unspecialised to specialised cells.	The role of the apical meristem of stem and root in the production of the primary plant body (details of layers **not** needed). Cell division and differentiation (**not** cambial activity).
3. Mammals reproduce, develop and grow.	
(a) Sexual reproduction in mammals requires specialised structures and cells.	The male and female urinogenital systems of a small mammal. Structure of ovary and testis. The production of gametes. The role of hormones in controlling gametogenesis, with particular reference to control of the sexual cycle in the female.
(b) Fusion of gametes produce a zygote.	Nuclear fusion in fertilisation.
(c) Early development is dependent on material resources.	The role of oestrogen and progesterone during pregnancy. The role of the placenta in the exchange of, or withholding of, substances between mother and developing embryo, by diffusion and by active transport, and in affording protection and immunity. The function of the amnion. The effect of the actions of the mother on fetal development.

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In addition to standard textbooks and articles in the Scientific American, New Scientist and Biological Sciences Review the following references may prove useful.

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Information on a rapid-cycling variety of *Brassica campestris* and its use in studying plant growth development and reproduction can be obtained from Science and Plants for Schools (SAPS) at Homerton College, Cambridge, CB2 2PH.

LIST B OPTIONS

General Information

The options in list B provide an opportunity to explore an area of Biology in more detail. These options will **only** be assessed by means of an investigative assignment and will test objective (d)(ii).

The layout for the options differs from that in the rest of the syllabus because the options merely suggest areas of study and the candidates will be assessed only on those aspects covered in their investigative assignment. Therefore, the extent to which each option should be taught, will depend largely on the nature of the assignments chosen by the students and the discretion of the teacher(s) involved. The aim is to provide a sufficient body of information to provide a framework on which to base the investigative assignment.

Teachers should be encouraged to use a variety of approaches for these options, for instance, students could present seminars, or teachers could use videos and mini-lectures on particular aspects of a given option.

It is expected that between 30-35 hours would be available for the options in list B; this time allocation should include teaching and guidance time for students as well as opportunity for individual work related to the assignments. The flexibility of teaching should make it possible for students in a centre, if they so wish, to choose different list B options for their investigative assignment, reflecting their various interests.

Investigative Assignments

Candidates will be expected to write a report on a practical investigation that they have carried out. These must be **individual** studies and should arise from the course work of one of the list B options. A wide interpretation of option content will be acceptable.

Option 5 (Animal Behaviour) — Data for practical assignments may be obtained by various means: field observations and laboratory studies are equally acceptable. Data may be recorded by direct observation or by the use of chart recorders, tape recorders, video cameras, film cameras or other suitable methods.

The attention of teachers and students is drawn to the guidelines issued by the DES and LEA with regard to safety and the use of animals in experiments.

Option 6 (Conservation) — A centre may choose to use a field course to provide its candidates with experience in ecological techniques and in the investigation of habitats, but care should be taken that each candidate's investigation is individual and that there is no shared data. The practical assignment should show an appreciation of the surrounding economic, political or social issues or an understanding of the historical or geographical and local, national or international issues, as appropriate to the assignment.

Option 7 (Microbiology and Biotechnology) — A practical assignment should be carried out under supervision and using safe aseptic techniques.

Option 8 (Aspects of Heterotrophic Nutrition) — Data from practical assignments could be obtained in a variety of ways, e.g. in the field as well as in the laboratory. The attention of teachers and students is drawn to the guidelines issued by the DES and LEA with regard to the use of animals in experiments.

In addition, attention is drawn to the **Notes for Guidance of Candidates** on page 29.

This part of the syllabus may be the most appropriate section in which to cover the interpretation and evaluation of data using statistical methods. Candidates should know how to apply a t-test and the χ^2 test. t-tests are of value in much of Biology, while the χ^2 test allows the evaluation of the results of breeding experiments and ecological sampling. Each of these tests is dealt with fully in many books on statistics for Biology.

Candidates are not expected to remember the following equations nor to remember for what the symbols stand. They are expected to be able to use the equations to calculate standard deviations, to test for significant differences between the means of two small unpaired samples and to perform a χ^2 test on suitable data from genetics or ecology. Candidates will be given access to the equations, the meaning of the symbols, a t-table and a χ^2 table.

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

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

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

Key to symbols

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

* Candidates should note that on some calculators the symbol σ may appear in place of the symbol s.

Candidates are not expected to be familiar with the term standard error, nor to appreciate the difference between s_n (σ_n) and s_{n-1} (σ_{n-1}). χ^2 tests will only be expected on one row of data. Candidates should have a brief understanding of what is meant by the term 'normal distribution' and appreciate levels of significance. (Tables will be provided by UCLES.) Questions involving the use of a t-test or a χ^2 test may be set on Papers 1, 2 or 3. Questions involving an **understanding** of the use of the tests may be set on Paper 5, but detailed computation will **not** be required.

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

OPTION 5 (30-35 hours)

ANIMAL BEHAVIOUR

Introduction

The study of animal behaviour is the study of how animals respond to their environment. An animal's environment includes its physical surroundings, the presence of other species which in some way interact with it, and the social environment the animal shares with the other members of its population. There are many disciplines which have contributed to our understanding of why animals behave as they do. Techniques and approaches drawn from ethology, behavioural ecology, neurophysiology, psychology, sociobiology and sociology are all relevant to the science of animal behaviour. In this Option comparisons may be made between non-human and human behaviour. The extent to which human behaviour is similiar to, but transcends, the behaviour of non-humans should be discussed. The limitations and dangers of extrapolating to humans directly from even our closest evolutionary relatives should be appreciated.

The following are examples of topics that could form the basis of a practical assignment:

Learning in kittens and cats.

The response of *Calliphora* larvae (or other named species) to light.

Orientation and feeding behaviour of flatworms.

Habituation in snails under different environmental conditions.

Feeding behaviour of the honey bee *Apis mellifera*: field observations and pollen analysis.

Mother-infant interaction in domestic dogs.

Effect of flock size on vigilance in a named species of bird (e.g. Starlings).

Maze learning in mice.

Hovering in kestrels (or kites or similar species of bird).

Intra- and inter-specific interactions between birds at bird tables.

The behaviour of large cats in zoos.

Foraging in butterflies.

Niche separation in an artificial community of tropical fish.

1. The Origins of Behaviour

   (a) Behaviour is the result of an interaction between an animal's genotype and the influences of its environment. Innate (instinctive) behaviour is behaviour which varies little between individuals of the same species.

   (Sign stimuli illustrated by Tinbergen's studies on stickleback courtship and reproduction.)

   (b) There are several sorts of learnt behaviour, each of which helps an organism to be more successful.

   (Habituation, conditioning, insight learning, latent learning and imprinting. The difference between memory and learning.)

2. Co-operation and Competition

   (a) Territories have costs and benefits. The application of the concept of territorial behaviour to human beings from the point of view of individuals, family groups, tribes and nations may be helpful but may also be misleading.

   (Examples of territorial behaviour from non-human species. Methods of marking and maintaining territories. Consideration should be given to the reasons for the behaviours involved as well as descriptions of them.)

   (b) Both aggression and altruism are seen in animals. Aggression may result from competition for food, mates, territory and dominance.

   (How do animals communicate to reduce the risk of aggression resulting in injury? A comparison of aggression in humans and non-humans.)

   (c) Social behaviour occurs in a wide range of animal species. There are advantages and disadvantages in leading a social existence as opposed to a solitary life.

   (The principles of social life in social insects and primates. Organisation of an insect society in terms of castes. Importance of communication within a species. Costs and benefits of group living.)

   (d) Altruism can evolve by natural selection. The problem of whether theories for the evolution of altruism in non-humans can be extrapolated to helping behaviour in humans.

   (The roles of kin selection, reciprocal altruism and group selection in the evolution of altruism. The notion of inclusive fitness. The application of the concept of the selfish gene.)

3. Interspecific Relationships

   Species do not live in isolation from one another. An association between two species may be to the benefit of both species (mutualism), may benefit one species but harm the other (parasitism or predation) or may benefit one species but neither harm nor benefit the other (commensalism).

   (Examples of the variety of interspecific associations.)

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OPTION 6 (30-35 hours)

CONSERVATION

Introduction

Conservation is the utilisation and management of resources in order to leave open or create the maximum number and kind of possible uses for the future. In the biological context, it can include everything from soil conservation on the land surface to the care of whole ecosystems, or the husbandry of wild fish populations in the sea to the protection of threatened species of wildlife in confined and small environments. Conservation is not just preservation but also the organic creation of new environments, such as those developing in reclaimed industrial wasteland. Conservation is therefore about management; in this it is akin to human involvement in industry and technology. Conservation demands of its practitioners both scientific and technical knowledge as well as qualities of judgement with which to assess conflicting human requirements. This syllabus section is designed to set out the scientific, technical and aesthetic principles of biological conservation.

The growth of the conservation movement in this century, in all its manifestations, is seen as a development complementary to the industrial and technological advances of our time.

The following are examples of topics that could form the basis of a practical assignment:

A study of the species colonising a suburban garden pond.

The effect of traditional management on a local woodland.

The effect on birdlife of reed-cutting in the management of a reedbed, e.g. for thatch.

An investigation of the effect of pollution on a local habitat.

The conservation of endangered species/rare breeds in captivity.

The effect of straw-burning on species numbers and diversity

The factors affecting the population size of a local fish.

The effect of trampling on a local open space or beauty spot.

A study of the factors affecting the reclamation of an industrial site.

1. The ecological basis for conservation
   - *(a)* Organisms interact with each other resulting in mutual dependence, competition and succession.
     (Synecological and autecological approaches. Sampling in an environment.)
   - *(b)* Population sizes are controlled by a number of factors.
     (Factors limiting population size may be density dependent or density independent. Effects of weather, predators, parasites, food and competition.)

2. Conservation management
   - *(a)* Conservation management is the art of controlling natural communities of both humans and the ecosystem. This first involves recording and monitoring change.
     (This could involve a practical study of a local conservation area or reserve, involving an analysis of the distribution or abundance of species and the effect of management.)
   - *(b)* Man manages some natural ecosystems to maximise productivity of a biological resource.
     (The management of fisheries or natural woodland for profit.)

(c) Industrial wasteland may be restored by knowledge of ecological succession.
(The restoration of wasteland to productive agriculture or amenity use.)

3. Conflicts with conservation
   (a) Agriculture and silvicultural practices may conflict with the need for wildlife conservation.
   (Examples could include the effects of hedgerow/tree removal, the drainage of wetlands, conifer afforestation of uplands.)
   (b) Man's urban life and industrial activities may conflict with the need for biological resources and species conservation.
   (Fresh or salt water pollution problems, acid deposition effects.)
   (c) Man's abuse of ecosystems may lead to long term environmental damage. This may be related to the expansion of human populations.
   (Examples such as overgrazing, desertification, watershed deforestation and soil erosion.)

4. The conservation movement
   (a) The conservation movement has grown from an awareness of the harm humans may do to their own environment and to other species of organism.
   (Conservation has an ethical basis. Not all things of value can be quantified economically.)
   (b) Conservation at the local and national level protects species and environments.
   (The work of an organisation concerned with some local aspects of conservation.)
   (c) Conservation needs to be tackled across national boundaries. The World Conservation Strategy.
   (The role of Governments in conservation legislation. The conservation of endangered species: gene banks, rare breeds and collections.)

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Owen, D. What is Ecology? Oxford University Press (1980)
Seaward, M.R.D. A Handbook for Naturalists, Constable (1981)
Spellerberg, I. & Hardes, S. Biological Conservation, Cambridge University Press (1990)
Timberlake, L. Only one Earth (Living for the Future) BBC Books/Earthscan (1987)
Tivy, J. & O'Hare, G. The Human Impact on the Ecosystem, Oliver and Boyd (1982)

The following may also be useful:

H.M.S.O. Transforming our Wasteland.
I.U.C.N. World Conservation Strategy. International Union for the Conservation of Nature.
Biological Sciences Review, Philip Allan Publishers Limited (5 × a year)
All areas of Britain are served by County Nature/Wildlife Conservation Trusts. The address of your local

Trust can be obtained from the Royal Society for Nature Conservation, 22, The Green, Nettleham, Lincoln, LN2 2NR. Through the R.S.N.C. and local Trusts many useful publications may be obtained.

For wider reference to environmental issues, contact should be made with the Council for Environmental Education at the School of Education, University of Reading, London Road, Reading, RG1 5AQ, from whom much information and other useful addresses may be obtained.

OPTION 7 (30-35 hours)
MICROBIOLOGY AND BIOTECHNOLOGY

Introduction

Biotechnology may be defined as the application of organisms, biological systems or processes to the manufacturing and service industries. For this option candidates should be able to relate some of the theoretical issues of microbiology to developments in modern biotechnology. The concentration on the technological applications will inevitably make this an option with social and environmental implications. It is envisaged that in this option the practical work will be an integral part of the teaching. In addition attention is drawn to the recommended practice in 'Microbiology — HMI guide for schools and non-advanced further education' (1985 HMSO).

The following are examples of topics that could form the basis of a practical assignment:

The effect of plant extracts on bacterial growth.

Vinegar production by *Acetobacter aceti.*

The production of biogas from landfill sites.

An investigation of the optimum conditions for the removal of sugar by yeast from waste water in the confectionery industry.

The effect of boric acid on algal growth.

The effect of different sugars on the growth of *Schizosaccharomyces pombe.*

A comparison of ethanol production by different 'home-brew' wine yeasts.

The effect of temperature on lactic acid production in the manufacture of yoghurt.

The use of pectinase to improve the yield of (named fruit) juice.

1. Different types of microorganism are used in industry
   (A review of characteristics sufficient to distinguish between viruses, bacteria, fungi and algae.)

2. Some standard techniques are used in laboratory study
   (Solid and liquid media, preparation of media, pouring plates, inoculation. Aseptic technique — importance and how to achieve asepsis.)

3. The growth of microorganisms can be measured in various ways; some of the factors affecting growth can be investigated
   (Growth curves. Measurement of growth by dilution plating, cell counts, turbidity of liquid media and dry matter production.)

4. Introduction to biotechnology
   (The historical development of the subject from baking and brewing techniques to present technologies.)

5. The applications of biotechnology have made a considerable impact on industry
   (a) Fermentation: experimental work with fermenters. Batch and continuous flow. Industrial use of fermentation. Necessity for temperature control and adequate aeration in large scale manufacture.
   (b) Dairying: cheese production, yoghurt production.
   (c) Medicine: use of monoclonal antibodies in diagnosis. The manufacture of antibodies.
   (d) Energy: biological fuels from urban and agricultural waste, biomass. Biogas and gasohol production.

(e) Food manufacture: plant cell culture, single cell protein, novel foods.

(f) Enzymes: use in washing powders, meat tenderising and fruit production. Immobilised enzymes.

(g) Tissue culture: basic techniques of plant tissue culture.

6. Genetic engineering; the manipulation of DNA has important applications in industry and medicine (Production of insulin and growth hormone.)

7. The future of biotechnology

   (Waste treatment and the environment. Biosensors. Concern for the responsible use of biotechnology.)

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D.E.S., Microbiology — an HMI guide for schools and non-advanced further education. H.M.S.O. (1985)
Flint, J., Some Aspects of Biotechnology in Agriculture, Secondary Science Curriculum Review (1989)
Hardcastle, J., Biotechnology in Agriculture, A.F.R.C. (1987)
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Taylor, J. Microorganisms and Biotechnology, Macmillan Educ. (1990)
Tomkins, S., Reiss, M. & Morris, C. Biology at Work, Cambridge University Press (1991)

The following Institute of Biology, Edward Arnold Studies in Biology:
Barnell, H.R. Biology of the Food Industry, 45, (1980) (out of print)
Berry, D.R. Biology of Yeasts, 140, (1982) (out of print)
Butcher, D.N. & Ingram, D.S. Plant tissue culture, 65, (1976) (out of print)
Sharp, J.A. Introduction to Animal Tissue Culture, 82, (1987) (out of print)
Warr, J.R. Genetic Engineering in Higher Organisms, 162, (1984)

The following New Studies in Biology, Institute of Biology, Edward Arnold:
Bickerstaff, G. Enzymes in Industry and Medicine (1987)
Maclean, N. Genes and Gene Regulation (1989)
Smith, J.E. Biotechnology, 2nd ed (1988)

Recent developments are well covered in New Scientist and some information on applications may be obtained from industrial firms. Trends in Biotechnology — (Elsevier), a monthly publication also has useful articles. See also Biological Sciences Review.

The National Centre for Biotechnology Education is based at the Department of Microbiology, University of Reading, and produces a Newsletter.

Information on experimental kits for Microbiology and Biotechnology and Fermentation can be obtained from the educational suppliers, Philip Harris Biological, Oldmixon, Weston-super-Mare, Avon, and Griffin and George, East Preston, West Sussex.

Schools should also note any specific advice issued by the Local Education Authority on the use of microorganisms.

OPTION 8 (30-35 hours)
ASPECTS OF HETEROTROPHIC NUTRITION

Introduction

Some diverse examples of heterotrophic nutrition are considered in this option and candidates should be aware of the fundamental differences between autotrophs and heterotrophs. It is envisaged that practical investigations will play an integral part in the teaching.

The following are examples of topics which could form the basis of a practical assignment:

Growth of bacteria or fungi on different media.

Changes in acidity in the mouth can be related to foods eaten.

Measurement of rates of passage of food through the guts of small animals (using markers such as carrot or beetroot).

Variability in the action of salivary amylase in different individuals.

Energy values of food determined and related to diets.

Investigation into the composition of flour.

An investigation into the nutritional quality of different foods.

An investigation into the vitamin C content of various foods.

An investigation into the parasites of the Holly leaf miner.

1. All heterotrophs depend on autotrophs
   The obtaining of energy-rich substances produced through photosynthesis.
   (Productivity of green plants in terms of carbohydrates, fats and proteins produced. Storage in leaves, stems, roots and seeds or grains; availability to heterotrophs.)

2. Heterotrophs obtain food in a variety of ways
   (Examples could include filter feeders, cropping by herbivores, predation by carnivores, mutualism and commensalism.)

3. Utilisation of complex organic materials by heterotrophs
   (a) Animals feed on animal and plant material to provide energy, materials for growth and repair, and other components necessary for healthy metabolism.
   (b) Complex organic molecules are broken down into simpler molecules.
   (Different diets are processed in different ways. Need for mechanical and chemical breakdown of food materials. Action of hydrolysing enzymes to facilitate absorption. A wide range of organisms may be considered.)

4. Parasitic and saprotrophic nutrition
   (a) Parasitism is a mode of nutrition adopted by a wide range of organisms which utilise organic compounds found in living organisms.
   (The study could include relationship with host and adaptations to parasitic nutrition. The trophic level occupied in the ecosystem should also be considered.)
   (b) Saprotrophism is a mode of nutrition involving external release of enzymes, mainly by bacteria and fungi, to break down organic materials in their surroundings.
   (The study could include details of substrate, adaptations to saprotrophic nutrition and the importance of saprotrophs in the recycling of nutrients in the ecosystem.)

Bibliography

In addition to standard textbooks and articles in the Scientific American, New Scientist and Biological Sciences Review, the following references may prove useful.

Bidwell, R.G., Plant Physiology, Collier Macmillan (1979)
Gill, N.T. & Vear, K.C., Agricultural Botany, Duckworth (1980) Volume 1
Dicotyledonous Crops, Volume 2 Monocotyledonous Crops
Janick, J. et al, Plant Science — An Introduction to World Crops, W.H. Freeman (1981)
Kershaw, D.R., Animal Diversity, University Tutorial Press (1983)
Miller, R.N., Plant Types, Hutchinson (1985) Volume 1 Fungi and Lichens
Robinson, M.A. & Wiggins, J.F., Invertebrates, Animal Types 1 and Vertebrates, Animal Types 2, Hutchinson (1971, 1973)

PAPER 9260/4
NOTES FOR THE GUIDANCE OF CANDIDATES

This paper is an investigative assignment based on one of the Options shown in List B which is carried out, completed and submitted by 30 April in the year of the examination.

The assignment should be an individual study based on a practical investigation of a topic from the chosen Option. Each completed assignment should be between 1500—2000 words in length, excluding headings, tables and appendices, and should consist of the following, clearly identifiable sections.

1. A clearly stated **title,** an **abstract** and a **contents list.**
2. An **introduction** which should briefly put the investigation in the context of the list B Option on which it is based. This should include a concise statement of the **hypothesis** that the investigation tests.
3. An account of the **method(s)** used in obtaining information. This should include the sequence of experimental or observational work undertaken and a clear statement of the sizes and frequency of samples or readings.
4. The **results** should be presented clearly and concisely. Tables, line graphs, bar charts, histograms, pie charts etc. are all commonly used and can be helpful, but they must be correctly derived from the observations. Raw data should be given in an appendix.

   Results should be analysed statistically where this is appropriate.
5. **Conclusions** or inferences based solely on the results obtained should be clearly stated, and they should be presented as tests of the initial hypothesis. The **discussion** should include implications and relevance of the conclusions if pertinent.
6. **Limitations, reliability** and **sources of error** should be evaluated and discussed and their possible effects on the reliability of the data should be noted.
7. Suggestions for any **modifications** to the original design should be made, based on the evaluation of the results.
8. A list of **acknowledgements** indicating the source and extent of any help that has been received.

Centres following the Syllabus for the first time should notify the Subject Officer at the beginning of the academic year in which they intend to start teaching, since it would be advisable for titles and brief descriptions of the proposed assignments to be sent for approval to UCLES. Outline Proposal Forms should be completed by each candidate and should state the title and aim of the investigation, its scope, the facilities needed, the methods to be adopted and the proposed analysis of the data obtained. The Forms must be sent for approval **well before** the work is begun and **not later than 1 November in the year preceding the examination.**

Pages must be numbered, and the assignment should be submitted in a light paper folder.

OPTION 8 (30-35 hours)

ASPECTS OF HETEROTROPHIC NUTRITION

Introduction

Some diverse examples of heterotrophic nutrition are considered in this option and candidates should be aware of the fundamental differences between autotrophs and heterotrophs. It is envisaged that practical investigations will play an integral part in the teaching.

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Measurement of rates of passage of food through the guts of small animals (using markers such as carrot or beetroot).

Variability in the action of salivary amylase in different individuals.

Energy values of food determined and related to diets.

Investigation into the composition of flour.

An investigation into the nutritional quality of different foods.

An investigation into the vitamin C content of various foods.

An investigation into the parasites of the Holly leaf miner.

1. All heterotrophs depend on autotrophs
   The obtaining of energy-rich substances produced through photosynthesis.
   (Productivity of green plants in terms of carbohydrates, fats and proteins produced. Storage in leaves, stems, roots and seeds or grains; availability to heterotrophs.)

2. Heterotrophs obtain food in a variety of ways
   (Examples could include filter feeders, cropping by herbivores, predation by carnivores, mutualism and commensalism.)

3. Utilisation of complex organic materials by heterotrophs
   (a) Animals feed on animal and plant material to provide energy, materials for growth and repair, and other components necessary for healthy metabolism.
   (b) Complex organic molecules are broken down into simpler molecules.
   (Different diets are processed in different ways. Need for mechanical and chemical breakdown of food materials. Action of hydrolysing enzymes to facilitate absorption. A wide range of organisms may be considered.)

4. Parasitic and saprotrophic nutrition
   (a) Parasitism is a mode of nutrition adopted by a wide range of organisms which utilise organic compounds found in living organisms.
   (The study could include relationship with host and adaptations to parasitic nutrition. The trophic level occupied in the ecosystem should also be considered.)
   (b) Saprotrophism is a mode of nutrition involving external release of enzymes, mainly by bacteria and fungi, to break down organic materials in their surroundings.
   (The study could include details of substrate, adaptations to saprotrophic nutrition and the importance of saprotrophs in the recycling of nutrients in the ecosystem.)

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Dicotyledonous Crops, Volume 2 Monocotyledonous Crops
Janick, J. et al, Plant Science — An Introduction to World Crops, W.H. Freeman (1981)
Kershaw, D.R., Animal Diversity, University Tutorial Press (1983)
Miller, R.N., Plant Types, Hutchinson (1985) Volume 1 Fungi and Lichens
Robinson, M.A. & Wiggins, J.F., Invertebrates, Animal Types 1 and Vertebrates, Animal Types 2, Hutchinson (1971, 1973)

INTERNAL ASSESSMENT OF PRACTICAL SKILLS
PAPER 9260/9
NOTES FOR THE GUIDANCE OF TEACHERS

INTRODUCTION

Some of the skills which should be developed as part of the A-level Biology course (for example, using apparatus and materials, observing, measuring and recording, and interpreting results and data) can be taught adequately only through the medium of practical work. A continuous assessment of practical work by the teacher throughout the A-level course allows direct observation of all the areas mentioned above. The scheme detailed below is intended to provide guidance for teachers in making the practical assessment, but should not exert an undue influence on the methods of teaching or provide a constraint on the practical work undertaken by candidates. Rather, the skills of the candidates should be assessed using practical work which the teacher finds most appropriate from the Core and from the Options. It is not expected that all of the practical work undertaken by the candidates would be appropriate for assessment.

The experimental skills to be assessed are given below:

A Using and organising procedures, apparatus and materials

B Observing, measuring and recording

C Interpreting experimental observations and data.

The three skills carry equal weighting.

Teachers must give their candidates opportunities to acquire a given skill before they make an assessment. Candidates should be informed when an assessment is to take place.

Each candidate must be assessed **twice** for each of the experimental skills. If a teacher wishes to assess each candidate on more than two occasions, the assessment scores finally recorded should represent the candidate's best performances **and should cover the complete skill descriptor. It is important that teachers read the notes below for each skill.**

Centres entering more than one teaching set must ensure that all staff assess their students to a common standard. It is not necessary, however, for all students to do the same work.

Criteria for Assessment of Experimental Skills

Each skill is assessed on a 6 point scale, level 6 being the highest level of achievement. A score of 0 is available if no work is submitted, or if the level of achievement is not worthy of credit.

Each of the skills is defined in terms of three levels of achievement at scores of 2/1, 4/3 and 6/5. It is not expected that every teaching set will include students covering the full ability range, but a realistic spread of scores should be awarded with 1 and 6 not being under-used.

SKILL A
USING AND ORGANISING PROCEDURES, APPARATUS AND MATERIALS

The candidate:

2/1 carries out procedures with limited understanding or carelessly; ignores, or carries out some instructions incorrectly; experiences considerable difficulty in handling apparatus and materials; takes few or inaccurate readings, with little regard for safety.

4/3 shows some understanding of procedures but may need some guidance in order to complete them; handles apparatus and materials adequately; takes the minimum number of readings with some regard for safety.

6/5 carries out procedures in a careful, methodical way without the need for assistance; handles apparatus and materials competently and correctly; takes the required readings with due regard for safety.

Note: Centres must ensure that assessment of this skill has regard for safety procedures being properly followed. It is important that the Moderators are supplied with evidence that safety has been assessed.

SKILL B
OBSERVING, MEASURING AND RECORDING

The candidate:

2/1 experiences considerable difficulty in reading scales and in making observations from the microscope; fails to record results systematically; produces graphs, tables and drawings which are incomplete or incorrect.

4/3 takes readings and makes observations from the microscope which are adequate but may be incomplete; records results but may need some help in selecting the correct format for presentation.

6/5 reads scales and observes microscopic specimens accurately; records the results in a suitable systematic form; produces graphs, tables and drawings which are complete and correctly labelled.

Note: Centres must ensure that the two pieces of work generating scores for this skill include a practical involving **measuring, tabulation** and **graph work, as well as** a practical involving **microscopy**.

SKILL C
INTERPRETING EXPERIMENTAL OBSERVATIONS AND DATA

The candidate:

2/1 shows limited ability to interpret results or observations with evidence of considerable misunderstanding; fails to use appropriate mathematical or statistical calculations; omits conclusions or makes conclusions which are not supported.

4/3 interprets results and observations with some success; makes some use of mathematical or statistical methods; puts forward conclusions which could be further developed.

6/5 interprets results and observations correctly; uses simple mathematical and statistical calculations, and notices trends in readings; makes sound and logical conclusions from the results or observations obtained.

Note: Centres must ensure that **one** of the practical exercises generating scores for this skill involves some **statistical analysis** of the results.

ADMINISTRATION AND REGULATIONS

Schools must indicate their intention to enter candidates for Paper 9 using the **early Provisional Entries Estimate Form (PE1A)** which is received in schools in the **September of the first year of the course.**

Paper 9 will not be available in the November examination, but candidates who entered for this paper in the June examination can have their assessment carried forward as Paper 89.

At whatever stage the assessments are done, the standards applied must be those exemplified by the stated criteria.

The marks for individual assessments should be recorded on the student's work as part of the normal feedback from the teacher. The final total score, as submitted to UCLES, should not be given to the students.

The recordings of assessment

UCLES will provide two forms for use with this scheme.

(i) The Student Record Card
(ii) The Centre Record Card

(i) *Student Record Card*

A record card should be used for each student.

In using the Record Card, the teacher should insert the date and experiment assessed, together with the appropriate scores for each of the abilities being assessed. Each experiment should be numbered so that the number and the date on which that experiment was carried out by the student can be entered on the Centre Record Card if finally selected by the teacher, see below.

(ii) *Centre Record Card*

This consists of a sheet, one side of which should be used to enter descriptions of the experiments used in the assessment scheme taken from the Student Record Card. The other side of the sheet should be used to record a summary of the scores for the whole centre. Two scores for each skill should be selected by the teacher and these should then be recorded on the Centre Record Card for each student. A separate sheet must be completed for each teaching set, unless they are taught by the same teacher. Copies should be retained at the Centre.

Note: For Skill A, the best two marks achieved by a student should be submitted. **For Skills B and C**, the teacher must ensure that the two marks submitted are from practicals which **between them** cover **all** the Skill criteria. See **Notes** for each skill above. It is recognised, however, that for these skills the two marks will be the best marks for the **subskills** within Skills B and C.

A pre-printed mark sheet, showing the index numbers and names of candidates, to be used for sending the total score to UCLES, will be forwarded to Centres in the year of examination. This mark sheet should be returned within 10 days of receipt.

The Student Record Cards and the Centre Record Card must be submitted to UCLES with the samples of students' work (see below).

Copies of the Centre Record Card(s) must be retained by the Centre for reference purposes.

Moderation

Centres entering more than one teaching set for this scheme must ensure that all staff assess their students to a common standard. It is not necessary, however, for all students to do the same work.

Schools will be required to submit all the assessed practical work, entered on the Centre Record Card, **from 8 students**. (Centres with **fewer than 8 candidates** should submit the assessed practical work, entered on the Centre Record Card, of **all candidates**.) The work of the candidates scoring the highest and lowest **total marks** should be submitted. The remaining candidates should be selected to cover the range between the highest and lowest **total mark**. The submitted work should be despatched to Cambridge by 30 April in the year of the examination.

It is essential that the work submitted includes the instructions given to the students, the marking scheme and/or assessment sheets used, and that the work is clearly marked and labelled. The work submitted should also include work marked by **all** the teachers involved in assessing candidates' work in a Centre.

Moderation will involve comparing samples of work and will not involve statistical moderation. On the basis of the moderation procedure, the marks of individual Centres may be adjusted, but the teacher's rank order will not normally be changed.