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A Level

Biology

Session: 2000
Type: Syllabus
Code: 9264

OCR

RECOGNISING ACHIEVEMENT

Biology (Linear)

9264, 9435

2000

former Cambridge UCLES syllabus

Advanced Level

Syllabus

NOTES

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 1 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 "OCR 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
9264

GCE ADVANCED LEVEL

*This subject may **not** be taken with Modules 4801, 4802, 4804, 4805, 4807 and 4851 of the Modular Science syllabus (but see below).*

Introduction

The syllabus has been designed to aid the transition from GCSE to A level. Candidates will be assumed to have achieved grade CC or above in a GCSE examination in Science: Double Award (or equivalent in Science: Biology).

The syllabus has been arranged in the form of Core content, to be studied by all candidates, and Options, of which two will be studied at A level.

The syllabus places emphasis on the applications of Biology and the impact of recent developments on the needs of contemporary society.

All candidates following this syllabus should be encouraged to:

- use secondary sources of information:
- use information technology (IT) to analyse, store and retrieve data and to model biological phenomena;
- communicate biological information orally, as well as in writing.

It is intended to keep the syllabus under frequent review, to ensure that it keeps abreast of knowledge in the biological sciences and other needs.

Links with A level Modular Biology (9524)

There are close links between this syllabus and the A level Modular Biology syllabus (9524) provided that particular Modules are selected for study.

If the **linear A level Biology** course incorporates Option 3 (Applications of Genetics), Option 4 (Growth, Development and Reproduction) and either Paper 4 (Extended Investigation) or Paper 9 (Teacher assessment of Experimental Skills), the course will mirror a **modular A level Biology** course incorporating the following Modules:

4801 (Foundation)
4802 (Central Concepts in Biology)
4804 (Transport, Regulation and Control)
4805 (Growth, Development and Reproduction)
4807 (Applications of Genetics)
4813 (Separate Skills Assessment)
or 4814 (Extended Investigation)

None of the above Modules may be taken in the same examination session as A level Biology.

Aims

The syllabus aims to:

(a) stimulate and both sustain and develop an interest in Biology;

(b) develop an understanding of biological facts and principles and an appreciation of their significance;

(c) emphasise the social, ethical and applied aspects of Biology;

(d) encourage an awareness of the contribution of Biology to the needs of society;

(e) develop an understanding of the scientific method and its application;

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

(g) provide a suitable foundation for the study of Biology or related courses in further higher education, and for professional courses which require students to have a knowledge of Biology when admitted;

(h) encourage respect for all forms of life.

Assessment Objectives

Using the knowledge and understanding specified in the syllabus, candidates should be able to:

(a) recall, recognise and show understanding of specific biological facts, terminology, principles, relationships, concepts and practical techniques;

(b) explain and interpret specific phenomena and effects in terms of biological principles;

(c) communicate biological information coherently in continuous prose and by means of tables, diagrams, drawings and graphs;

(d) manipulate numerical and non-numerical biological information;

(e) demonstrate their knowledge and understanding of the social, ethical, economic, environmental and technological implications and applications of biology;

(f) use biological facts and principles to construct hypotheses and make predictions;

(g) identify and bring together information to give a concise and coherent explanation or description;

(h) assess the validity of biological information, experiments, inferences and statements;

(i) devise and plan experimental activities;

(j) select and use appropriate techniques to carry out experimental activities;

(k) interpret, evaluate and communicate the results of their experimental activities.

Relationship Between the Assessment Objectives and Assessment Components

This is given in the Assessment Grid below.

	Assessment Objectives	Weighting(%)	Assessment Components
Knowledge and Understanding	*(a), (c)*	50	Papers 1, 2, 3
Application of Knowledge and Understanding	*(b), (d), (e), (f), (g), (h)*	30	Papers 1, 2, 3
Experimental skills	*(i), (j), (k)*	20	Papers 4*, 5*, 6*, 9*

* Alternative papers

Fifteen percent of the total marks will be awarded for awareness of the social, economic, environmental and technological implications and applications of Biology. These will be awarded within the 'Knowledge and Understanding' and the 'Application of Knowledge and Understanding' categories.

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 43).

Scheme of Assessment

(Papers 1, 2 and 3 are compulsory. Paper 5 ***must*** *be taken with Paper 6, and these two papers* ***together*** *are alternative to Papers 4 or 9. Paper 9435 is optional)*

Paper	*Description*	*Duration*	*Marks*	*Weighting*
1	Structured questions (may include data response and comprehension) and free-response questions	2½ h	100	35%
2	Multiple Choice	1 h	40	15%
3	Short answer questions and a free-response question	1½ h	75	30%
4	Teacher-assessed Extended Investigation	—	36	20%
5	Practical examination	2½ h	60	13⅓%
6	Skill A teacher-assessed	—	12	6⅔%
9	Teacher-assessed Experimental Skills	—	36	20%
9435	Special Paper	2½ h	75	

Papers 2 and 3 will be timetabled together

Paper 1 (2½ h, 100 marks scaled to a mark out of 70)

Questions will be set on each of the Option syllabuses but a knowledge of Core material may be required. The questions will test Assessment Objectives *(a), (b), (c), (d), (e), (f), (g)* and *(h)*. Candidates will be required to answer questions on each of **two** Option syllabuses.

For each Option, there will be compulsory structured/data-response/comprehension-type questions. A further question will be presented in an either/or form and will be a free-response question.

Paper 2 (1 h, 40 marks scaled to a mark out of 30)

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 Assessment Objectives *(a), (b), (d), (e), (g)* and *(h)*.

Paper 3 (1½ h, 75 marks scaled to a mark out of 60)

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 Assessment Objectives *(a), (b), (c), (d), (e), (f), (g)* and *(h)*.
In this paper, a maximum of 4 marks will be allocated to the assessment of Quality of Language.

Paper 4 (Alternative to Papers 5, 6 and 9) (36 marks scaled to a mark out of 40)

This paper will be an Extended Investigation which should be an **individual** study. The investigation may be **either** Laboratory/Fieldwork based **or** Work-related, representing no more than 15 hours practical work. (See pages 41 to 49.)

The Extended Investigation will be teacher-assessed and candidates will be expected to show evidence of the following skills (Assessment Objectives *(i)*, *(j)* and *(k)*.

A Planning
B Implementing
C Interpreting and Concluding

The investigation should be no more than 2500 words (excluding headings, tables, graphs and appendices).

Pages must be numbered and the Extended Investigations should be submitted in light paper folders and **not** in heavy ring binders. A Teacher's Handbook is available.

Paper 5 (Alternative to Papers 4 and 9) (2½ h, 60 marks scaled to a mark out of 26¾)

This paper will be a practical examination which is set and marked by OCR. 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. Alternatively, interactive videos or similar may be used, rather than actual dissection of material.

Candidates will be expected to show evidence of the following skills (Assessment Objectives *(i)*, *(j)* and *(k)*) in handling of familiar and unfamiliar biological material:

B Implementing
C Interpreting and Concluding

Paper 6 (Additional to Paper 5) (12 marks scaled to a mark out of 13⅓)

This paper will be teacher assessment of Experimental Skill **A, Planning,** and **must be taken with Paper 5**. Further information is given on pages 50 to 55. A Teacher's Handbook is available.

Paper 9 (Alternative to Papers 4, 5 and 6) (36 marks scaled to a mark out of 40)

This paper will be teacher assessment of Experimental Skills. This is intended to reflect practical work carried out throughout the course, and will test the same skills as Paper 4 (see above). Further information is given on pages 56 to 63. (Not available in the November examination, but see note concerning Paper 89). A Teacher's Handbook is available.

Special Paper **(9435)** (2½ h)

This paper (available in June only) 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 **eleven** questions of which three questions will be based on the Core syllabus and two each of eight questions will be biased towards a different Option Syllabus. 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. Candidates may be entered for the Special Paper whether or not they have been entered for the 'A' level syllabus.

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 86

This paper applies to candidates who have taken the June examination and who have elected to carry forward their Skill A assessment to the November examination. The term *Paper 86* 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.

A candidate's A level grade is determined solely by the aggregation of their marks in the various Papers, with the exception of the Special Paper (see notes above), i.e. candidates are not required to achieve a certain level of performance in any individual Paper.

Structure of Syllabus

The syllabus is divided into two parts:

(i) The Core syllabus - to be studied by all candidates and to take up to 135 hours of teaching time.

There are ten Core sections:

A Cell Structure,
B Biological Molecules,

C Enzymes,
D Cell and Nuclear Division,
E Genetic Control and Inheritance,
F Inherited Change and Evolution,
G Energetics,
H Ecology,
I Transport,
J Regulation and Control.

(ii) The Option syllabuses – candidates will study and be assessed on **two** of the following Options.

Each Option is to take up to 45 hours of teaching time.

1 **Biodiversity**
2 **Applied Plant and Animal Science**
3 **Applications of Genetics**
4 **Growth, Development and Reproduction**

The syllabus is based on a total of 260 hours with 225 hours used for teaching the Core and Options, and 35 hours available for the Extended Investigation, further practical work, or for assessment of Experimental Skills.

Subject Content

The syllabus content for the Core and Options is presented as Learning Outcomes. The examination will assess the candidate's knowledge and understanding of these.

It is expected that practical activities will underpin the teaching of the whole syllabus.

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

CORE SYLLABUS (135 hours)

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

A Cell Structure

Content

The microscope in cell studies.
Cells as the basic units of living organisms, grouped into tissues and organs.
Characteristics of eukaryotic and prokaryotic cells.
Detailed structure of typical animal and plant cells as seen under the light and electron microscope.
Outline functions of organelles in plant and animal cells.
The fluid mosaic model of membrane structure.
The movement of substances into and out of cells.

Learning Outcomes

Candidates should be able to:

(a) describe and interpret drawings and photographs of typical animal and plant cells as seen under the light microscope.

(b) use a graticule and stage micrometer to measure cells and be familiar with the units (millimetre, micrometre, nanometre) used in cell studies.

(c) explain and distinguish between *resolution* and *magnification*, with reference to light microscopy and electron microscopy.

(d) describe and interpret drawings and photographs of typical animal and plant cells as seen under the electron microscope, recognising the following membrane systems and organelles - rough and smooth endoplasmic reticulum, Golgi apparatus, mitochondria, ribosomes, lysosomes, chloroplasts, cell surface membrane, nuclear envelope, centrioles, nucleus and nucleolus. (Reference should be made to the preparation techniques for electron microscopy.)

(e) outline the functions of the membrane systems and organelles listed in *(d).*

(f) compare and contrast the structure of typical animal and plant cells.

(g) explain the meaning of the terms *tissue* and *organ,* and state examples in animals and plants.

(h) draw plan diagrams of tissues (including a transverse section of a dicotyledonous leaf) and calculate the linear magnification of drawings.

(i) describe the structure of a prokaryotic cell, and compare and contrast the structure of prokaryotic cells with eukaryotic cells.

(j) describe and explain the fluid mosaic model of membrane structure, including an outline of the roles of phospholipids, cholesterol, glycolipids, proteins and glycoproteins.

(k) outline the roles of membranes within cells and at the surface of cells.

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

(m) investigate the effects on plant cells of immersion in solutions of different water potentials.

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

B Biological Molecules

Content

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

Learning Outcomes

Candidates should be able to:

(a) carry out tests for reducing and non-reducing sugars (including quantitative use of the Benedict's test), the iodine in potassium iodide solution test for starch, the emulsion test for lipids, and the biuret test for proteins.

(b) describe the structure of the ring forms of alpha and beta glucose.

(c) describe the formation and breakage of a glycosidic bond.

(d) describe the molecular structure of starch (amylose), glycogen and cellulose and relate these structures to their functions in living organisms.

(e) describe the molecular structure of a triglyceride and a phospholipid, and relate these structures to their functions in living organisms.

(f) describe the structure of an amino acid and the formation and breakage of a peptide bond.

(g) explain the meaning of the terms *primary structure, secondary structure, tertiary structure* and *quaternary structure* of proteins, and describe the types of bonding (hydrogen, ionic, disulphide and hydrophobic interactions) which hold the molecule in shape.

(h) outline the molecular structure of haemoglobin, as an example of a globular protein, and of collagen as an example of a fibrous protein, and relate these structures to their functions. (The importance of iron in the haemoglobin molecule should be emphasised.)

(i) describe and explain the roles of water in living organisms, and as an environment for organisms.

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

C Enzymes

Content

Mode of action of enzymes.

Learning Outcomes

Candidates should be able to:

(a) explain that enzymes are globular proteins which catalyse metabolic reactions.

(b) explain the mode of action of enzymes in terms of an active site, enzyme/substrate complex, lowering of activation energy and enzyme specificity.

(c) describe and explain the effects of pH, temperature, enzyme concentration and substrate concentration on enzyme action.

(d) follow the time course of an enzyme-catalysed reaction, by measuring rates of formation of products (for example using catalase) or rate of disappearance of substrate (for example using amylase).

(e) investigate the effects of temperature, pH, enzyme concentration and substrate concentration on the rate of enzyme-catalysed reactions, and explain these effects.

(f) explain the effects of competitive and non-competitive inhibitors on the rate of enzyme activity.

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

D Cell and Nuclear Division

Content

Replication and division of nuclei and cells.
Understanding of chromosome behaviour in mitosis and meiosis.
Effect of meiosis on chromosome number and variation.

Learning Outcomes

Candidates should be able to:

(a) explain how growth, repair and asexual reproduction can be brought about by cell division by mitosis.

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

(c) explain how cancer is a result of uncontrolled cell division, and list factors which can increase the chances of cancerous growth.

(d) describe, with the aid of diagrams, the behaviour of chromosomes during the mitotic cell cycle and the associated behaviour of the nuclear envelope, cell membrane and centrioles. (Names of the main stages are expected.)

(e) make, stain and observe microscopically a root tip squash.

(f) explain what is meant by homologous pairs of chromosomes.

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

(h) describe, with the aid of diagrams, the behaviour of chromosomes during meiosis, and the associated behaviour of the nuclear envelope, cell membrane and centrioles. (Names of the main stages are expected, but **not** the sub-divisions of prophase.)

(i) explain how meiosis can lead to variation.

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

E Genetic Control and Inheritance

Content

The structure and replication of DNA.
The role of DNA in protein synthesis.

Learning Outcomes

Candidates should be able to:

(a) describe the structure of RNA and DNA and explain the importance of base pairing and hydrogen bonding.

(b) explain how DNA replicates semi-conservatively during interphase.

(c) state that a gene is a sequence of nucleotides as part of a DNA molecule, which codes for a polypeptide.

(d) describe the way in which the nucleotide sequence codes for the amino acid sequence in a polypeptide.

(e) describe how the information on DNA is used to construct polypeptides, including the role of messenger RNA, transfer RNA and the ribosomes.

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

(g) explain how a change in the sequence of the DNA nucleotide may affect the amino acid sequence in a protein, and hence the phenotype of the organism.

(h) describe sickle cell anaemia and phenylketonuria (PKU) as examples of gene mutations.

(i) outline the principles of gene manipulation in biotechnology, with reference to the synthesis of human insulin by bacteria.

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

F Inherited Change and Evolution

Content

The passage of information from parent to offspring.
The nature of genes and alleles and their role in determining the phenotype.
Monohybrid and dihybrid crosses.
Natural and artificial selection.

Learning Outcomes

Candidates should be able to:

(a) explain how DNA is transferred from parent to offspring in sexual reproduction.

(b) explain the terms, *allele*, *dominant*, *recessive*, *codominant*, *homozygous* and *heterozygous*.

(c) use genetic diagrams to solve problems involving monohybrid and dihybrid crosses, including those involving sex linkage, codominance and multiple alleles (but **not** involving autosomal linkage or epistasis).

(d) use genetic diagrams to solve problems involving test crosses.

(e) explain, with examples, how the environment may affect phenotype.

(f) explain why sexually produced organisms vary.

(g) explain why variation is important in selection.

(h) explain how all organisms can potentially over produce.

(i) explain, with examples, how environmental factors act as forces of natural selection.

(j) explain how natural selection may bring about evolution.

(k) explain the meaning of the term *species*, and describe the classification of species into taxonomic groups (genus, family, order, class, phylum, kingdom).

(l) describe one example of artificial selection.

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

G Energetics

Content

The need for energy in living organisms.
Photosynthesis as an energy trapping process.
Respiration as an energy releasing process.
Aerobic respiration.
Anaerobic respiration.

Learning Outcomes

Candidates should be able to:

(a) outline the need for energy in living organisms (anabolic reactions, active transport, movement, maintenance of body temperature).

(b) describe the universal role of ATP as the energy 'currency' in all living organisms.

(c) explain the photoactivation of chlorophyll resulting in the conversion of light energy into chemical energy of ATP and reduction of NADP (**no** biochemical detail is required).

(d) describe in outline the Calvin cycle involving the light independent fixation of carbon dioxide by combination with a 5C compound (RuBP) to yield GP (PGA), a 3C compound, and the subsequent conversion of GP into carbohydrates, amino acids and lipids. (Regeneration of RuBP should be understood in outline only and knowledge of C_4 and CAM plants is **not** required.)

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

(f) discuss limiting factors in photosynthesis and carry out investigations on the effects of limiting factors, such as light intensity, on the rate of photosynthesis.

(g) outline glycolysis, as phosphorylation of glucose and the subsequent 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.

(h) explain that when oxygen is available, pyruvate is converted to acetyl (2C) coenzyme A which then combines with oxaloacetate (4C) to form citrate (6C).

(i) outline the Krebs cycle occurring in the mitochondrion, explaining that citrate is reconverted to oxaloacetate in a series of small steps (**no other** biochemical detail is required).

(j) explain that these processes involve decarboxylation and dehydrogenation, and describe the role of NAD.

(k) describe oxidative phosphorylation occurring in the mitochondrion, including the role of oxygen (**no** details of carriers are required).

(l) explain the production of a small yield of ATP from anaerobic respiration and the formation of ethanol in yeast and lactate in mammals.

(m) carry out investigations of the effect of temperature on respiration rate, using simple respirometers.

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

H Ecology

Content

Levels of ecological organisation.
Recycling of nutrients.
Energy flow through ecosystems.
Effects of human activities.

Learning Outcomes

Candidates should be able to:

(a) define the terms *habitat, niche, population, community* and *ecosystem,* and state examples of each.

(b) explain the terms *producer, consumer* and *trophic level* in the context of food chains and food webs.

(c) describe the way in which energy flows along food chains and webs.

(d) explain how energy losses occur along food chains, and discuss the efficiency of energy transfer between trophic levels.

(e) describe and explain pyramids of energy and biomass.

(f) describe how carbon and nitrogen are cycled within an ecosystem, including the roles of microorganisms.

(g) describe and explain how the use of fossil fuels and deforestation may affect the environment and discuss measures which could be taken to reduce the harmful consequences.

(h) discuss the possible conflict of interest between production and conservation, with reference to the use and effects of nitrogen-containing fertilisers, and describe alternatives to their use.

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

Note: *An ecosystem should be studied in relation to an area familiar to the candidates.*

I Transport

Content

Transport in plants and mammals.

Learning Outcomes

Candidates should be able to:

(a) describe the structure and explain the function of xylem vessels, sieve tube elements and companion cells, and be able to recognise these in sections of an herbaceous dicotyledonous leaf and stem under the light microscope.

(b) explain the movement of water between plant cells and between them and the environment in terms of water potential (terminology described in the IOB's publication *Biological Nomenclature* should be used; no calculations involving water potential will be set).

(c) define the term *transpiration* and explain that transpiration is an inevitable consequence of gaseous exchange in plants.

(d) describe the pathway and explain the mechanisms by which water is transported from roots to leaves.

(e) explain translocation as an energy requiring process transporting assimilates, especially sucrose, between the leaves and other parts of the plant.

(f) describe the structure of arteries, veins and capillaries in relation to their functions and be able to recognise these vessels under the light microscope.

(g) list the major components of blood and describe their functions in transport only.

(h) explain the role of haemoglobin in the transport of O_2 and explain the significance of the oxygen dissociation curves of haemoglobin at different CO_2 levels (Bohr effect).

(i) explain the significance of the difference in affinity for oxygen between haemoglobin and myoglobin.

(j) describe the structure of the heart and cardiac cycle.

(k) explain how heart action is initiated and controlled.

(l) discuss the possible links between coronary heart disease and diet.

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

J Regulation and Control

Content

Homeostasis.
Nervous and hormonal control.
Excretion.

Learning Outcomes

Candidates should be able to:

(a) recognise the need for control in organised systems and explain the principles of homeostasis in terms of receptors, effectors, and negative feedback.

(b) describe and explain the homeostatic functions of the liver in terms of carbohydrate metabolism, fat metabolism, storage of vitamins A, B, and D, synthesis of plasma proteins, breakdown of erythrocytes, detoxification and deamination of amino acids.

(c) recognise the need for communication systems within organisms.

(d) describe the structure of sensory and motor neurones and outline their functions in a reflex arc.

(e) describe and explain the transmission of an action potential along a myelinated neurone. (The importance of Na^+ and K^+ ions in the impulse transmission should be emphasised.)

(f) describe the structure of a cholinergic synapse and explain how it functions, including the role of Ca^{2+} ions.

(g) outline the roles of synapses in the nervous system.

(h) explain what is meant by an endocrine gland, with reference to the islets of Langerhans in the pancreas.

(i) explain how the blood glucose concentration is regulated by insulin and glucagon.

(j) define the term *excretion* and explain the importance of removing nitrogenous and other compounds from the body.

(k) describe the gross structure of the kidney and the detailed structure of the nephron and associated blood vessels. (Candidates are expected to be able to interpret the histology of the kidney as seen in sections under the light microscope.)

(l) explain the functioning of the kidney in the control of water and metabolic waste levels of the body fluids. (The note concerning osmoregulation in animals in the IOB's publication *Biological Nomenclature* should be consulted.)

(m) outline the mechanism of dialysis in the case of kidney failure.

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

OPTION 1 (45 hours)

BIODIVERSITY

Introduction

This Option is intended to develop:

- a due respect for all living organisms and their environment;
- an appreciation of the wide diversity of living organisms based on first-hand observations;
- an understanding of how plants and animals are classified according to the 5 kingdom classification of Margulis and Schwartz (1988);
- an appreciation of the wide range of uses of microorganisms in biotechnology;
- an understanding of how some animals are adapted to their environment;
- an understanding of the need to maintain biodiversity through conservation strategies.

1 Diversity of Microorganisms

Content

Viruses.
Escherichia coli.
Penicillium.
Paramecium.
Chlorella.
Uses of bacteria, fungi and algae in biotechnology.

Learning Outcomes

Candidates should be able to:

(a) review briefly the characteristics and mode of replication of viruses.

(b) describe briefly the structure and reproduction of *Escherichia coli.*

(c) describe the structure and explain the mode of nutrition of *Penicillium.*

(d) describe the structure of *Paramecium.*

(e) describe the structure of *Chlorella.*

(f) discuss the range of uses of bacteria, fungi and algae in biotechnology.

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

2 Plant and Animal Diversity

Content

Bryophytes, filicinophytes, coniferophytes and angiospermophytes.
Cnidarians, platyhelminths, nematodes, annelids, molluscs, arthropods, echinoderms and chordates.

Learning Outcomes

Candidates should be able to:

(a) list the diagnostic features of bryophytes, filicinophytes, coniferophytes and angiospermophytes.

(b) identify the differences between monocotyledon plants and dicotyledon plants with reference to internal and external structure.

(c) explain the extent to which bryophytes, filicinophytes, coniferophytes and angiospermophytes are adapted to life on land.

(d) list the **diagnostic** features of the following phyla: Cnidaria, Platyhelminthes, Nematoda, Annelida, Mollusca, Arthropoda, Echinodermata and Chordata.

(e) distinguish between *diploblastic organisation* and *triploblastic organisation.*

(f) distinguish between the terms *acoelomate* and *coelomate.*

(g) compare the body plans of a cnidarian, an annelid, an arthropod and a chordate.

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

3 Animal Adaptations

Content

Feeding methods.
Gaseous exchange in water and in the air.
Movement in water and on land.

Learning Outcomes

Candidates should be able to:

(a) survey the range of feeding methods of animals, and consider the possible implications for humans, with reference to a cnidarian, a named endoparasitic platyhelminth, an earthworm, a locust and an aphid.

(b) assess the problems of gaseous exchange in water and in air.

(c) compare the methods of gaseous exchange in a locust, a bony fish and a human, with reference to the type of gaseous exchange surface, the medium for gaseous exchange and the ventilation mechanism required.

(d) assess the problems of movement in water and on land.

(e) describe and explain locomotion in an earthworm, a locust and a bony fish.

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

4 Maintaining Biodiversity

Content

Conservation involves preservation, management and reclamation.
The African elephant.
Tropical rain forest.
Conservation may involve conflicts of interest.

Learning Outcomes

Candidates should be able to:

(a) discuss the economic and ethical reasons for maintaining biodiversity.

(b) explain, using specific examples, how conservation may involve preservation, management and reclamation, and is a dynamic process.

(c) discuss the conservation of the African elephant with regard to population numbers, reasons for concern, measures introduced and international cooperation required.

(d) discuss the conservation of tropical rain forest with regard to ecological importance, reasons for decline and international measures that need to be, or are being, taken.

(e) appreciate the conflicts of interest in *(b)*, *(c)* and *(d)* above and discuss the possible views of the local population, tourists, conservationists and the governments of the countries concerned.

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

OPTION 2 (45 hours)

APPLIED PLANT AND ANIMAL SCIENCE

Introduction

This Option is intended to develop:

- an understanding of the far reaching effects of applied science in food production;
- an appreciation that Biology can be studied in relation to the needs of people;
- an understanding of the factors that contribute to plant growth and yield;
- an understanding of the global distribution of crops and farm animals;
- an appreciation that increased productivity has had considerable social and economic effects;
- some appreciation of the overproduction of food in Europe and North America;
- an appreciation of the problems of food supply in developing countries and the conflict with production of cash crops.

1 Plant Metabolism and Productivity

Content

Photosynthesis in C_3 and C_4 plants.
Factors affecting the growth of crop plants.
Efficiency of energy conversion.
Measurement of crop yields.
Use of plant growth regulators.

Learning Outcomes

Candidates should be able to:

(a) describe the structural differences between C_3 and C_4 plants.

(b) outline the C_4 pathway in photosynthesis in terms of the combination of CO_2 with a 3C compound, phosphoenolpyruvate (PEP) to form a 4C organic acid prior to the Calvin cycle reactions.

(c) explain the economic importance of C_3 plants as crops in temperate regions and C_4 plants as crops in tropical regions.

(d) describe the structure and function of a stoma. (Reference should be made to turgor changes in the guard cells.)

(e) explain the effects of light intensity, temperature, CO_2, water and nutrients on the growth of crop plants.

(f) describe the efficiency of energy conversion, in terms of intercepted radiation and dry matter production.

(g) describe the measurement of yields at harvest in terms of total biomass, harvestable dry matter and digestible energy.

(h) outline the roles of auxins, gibberellins, cytokinins and abscisic acid as plant growth regulators.

(i) describe how plant growth regulators are used to improve plant performance with reference to seedless fruits and rooting compounds.

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

2 Soil Fertility

Content

N, P and K in plant growth and metabolism.
Maintenance of soil fertility.
Nitrogen fixation.
Irrigation and drainage.

Learning Outcomes

Candidates should be able to:

(a) state the roles of nitrogen (N), phosphorus (P) and potassium (K) in plant growth and metabolism.

(b) explain the need for significant inputs of N, P and K.

(c) discuss the importance of soil texture, aeration, pH and water content (field capacity) on the growth of plants.

(d) explain how soil is improved by adding lime and farmyard manure.

(e) describe the role of *Rhizobium* in nitrogen fixation and discuss its possible use as an alternative to fertilisers in the future.

(f) assess the need for irrigation and drainage for the growth of crop plants.

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

3 Crop Production

Content

Global distribution of crop plants.
Crop cultivation.
Reduction of crop yields by insect pests, weeds and fungal pathogens.
Chemical and biological control of insect pests.
Monoculture.

Learning Outcomes

Candidates should be able to:

(a) describe the global distribution of cassava, maize, rice and wheat.

(b) discuss the reasons for the choice of crops grown in different areas of the world. (Reference should be made to nutritional, environmental, cultural and economic factors.)

(c) describe the cultivation of **either** wheat **or** maize with reference to ploughing, drilling, pest, weed and disease control, fertiliser input, harvesting and storage.

(d) explain how insect pests, weeds and a named fungal pathogen reduce crop yields and quality.

(e) discuss the advantages and disadvantages of chemical and biological control of insect pests.

(f) discuss the advantages and disadvantages of monoculture.

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

4 Livestock Production

Content

Factors affecting choice of livestock.
Intensive and extensive production.
Animal husbandry and disease control.
Efficiency of energy conversion.
Implications of intensive production.

Learning Outcomes

Candidates should be able to:

(a) discuss the social, environmental and economic features that determine the choice of animals to be reared.

(b) distinguish between *intensive* and *extensive* livestock production.

(c) describe the production of **either** pigs **or** cattle with reference to nutritional requirements, pest and disease control.

(d) discuss the efficiency of energy conversion in livestock and the ways in which productivity is maximised.

(e) discuss the implications of intensive animal production with reference to environmental impact and animal welfare.

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

5 The World Food Problem

Content

Production and distribution of food around the world.
Problems of food surpluses and shortages.

Learning Outcomes

Candidates should be able to:

(a) discuss the uneven distribution of food resources in the world.

(b) discuss the problems of surpluses in Europe and North America in terms of storage and cost of subsidies.

(c) discuss the problems of food supply in developing countries and the conflict between growing crops for export and food for local consumption.

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

OPTION 3 (45 hours)

APPLICATIONS OF GENETICS

Introduction

This Option is intended to develop:

- an understanding of the causes of variation;
- an understanding of the principles and uses of selective breeding;
- an understanding of the importance of genetic diversity;
- an understanding of the ways in which organisms can be modified by genetic engineering;
- an understanding of some aspects of human genetics and an appreciation of their medical, ethical and social implications.

1 Variation

Content

The effect of genotype and environment on phenotype.

Learning Outcomes

Candidates should be able to:

(a) explain what is meant by *variance.*

(b) describe the difference between continuous and discontinuous variation.

(c) explain the genetic basis of continuous and discontinuous variation by reference to the number of genes which control the characteristic.

(d) recognise that both genotype and environment contribute to phenotypic variance. ($V_P = V_G + V_E$) (**No** calculations of heritability will be expected.)

(e) describe two examples of the effect of the environment on the phenotype.

(f) describe interaction at one locus (dominance).

(g) describe gene interaction between loci (epistasis).

(h) use genetic diagrams to predict phenotypic ratios in problems involving epistasis.

(i) use genetic diagrams to explain the meaning of the terms *linkage* and *crossing-over.*

(j) explain the effect of linkage and crossing-over on the phenotypic ratios from dihybrid crosses.

(k) use the chi^2 test to test the significance of differences between observed and expected results. (The formula for the chi^2 test will be provided.)

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

2 Selective Breeding

Content

The desirable characteristics of organisms can be selected by selective breeding.

Learning Outcomes

Candidates should be able to:

(a) outline the principle of selective breeding and explain why selective breeding is carried out.

(b) explain, with practical details, how the process of selective breeding may be carried out in one named plant example and one named animal example.

(c) discuss the similarity of selective breeding to the evolutionary process.

(d) explain the use of progeny testing.

(e) discuss the advantages and disadvantages of artificial insemination (AI).

(f) describe the use of, and the techniques used in, embryo transplantation.

(g) discuss the social and ethical implications of the use of AI, *in vitro* fertilisation and embryo transplantation in humans.

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

3 Genetic Diversity

Content

The problems of inbreeding.
The need to maintain genetic resources.
The development of resistance.

Learning Outcomes

Candidates should be able to:

(a) describe the harmful effects of inbreeding.

(b) explain the need to maintain a gene bank for possible future use, including conserving wild types and rare breeds as genetic resources.

(c) describe the maintenance and use of seed banks and sperm banks.

(d) describe the process of cloning plants from tissue culture.

(e) describe the genetic basis of resistance.

(f) explain, with specific examples, how selective breeding is used to produce disease-resistant varieties in plants and animals.

(g) describe the development of antibiotic resistance in bacteria and pesticide resistance in insects and discuss the implications of the development of such resistance.

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

4 Genetic Engineering

Content

Organisms can be modified by genetic engineering.

Learning Outcomes

Candidates should be able to:

(a) outline the use of restriction enzymes in removing sections of the genome.

(b) describe the formation of recombinant DNA.

(c) describe one use of genetic engineering in agriculture.

(d) discuss the benefits and hazards of genetic engineering, with reference to specific examples.

(e) discuss the ethical implications of genetic engineering.

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

5 Human Genetics

Content

Genetic disorders in humans.
Genetic screening and genetic counselling.
Gene therapy, its possible benefits and hazards.
Genetic fingerprinting and its uses.
The significance of genetic constitution for tissue compatibility in transplant surgery.

Learning Outcomes

Candidates should be able to:

(a) describe cystic fibrosis, Huntington's disease (chorea) and Down's syndrome in humans, and explain how they are inherited.

(b) describe how genetic screening is carried out.

(c) discuss the advantages and disadvantages of genetic screening and the need for genetic counselling.

(d) explain the theoretical basis of gene therapy and discuss its possible benefits and hazards.

(e) explain the theoretical basis of genetic fingerprinting and outline how it is carried out.

(f) explain the significance of genetic compatibility in transplant surgery, with reference to ABO blood groups and the major histocompatibility (HLA) system.

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

OPTION 4 (45 hours)

GROWTH, DEVELOPMENT AND REPRODUCTION

Introduction

This Option is intended to develop:

- an understanding of growth, development and reproduction in a range of organisms;
- an understanding of growth and reproduction in the life cycle of an organism;
- an understanding of methods of investigating and measuring growth;
- an understanding of the role of hormonal control in growth and reproduction.

1 Growth and Development

Content

Growth is an irreversible increase in mass.
Development results in an increase in the complexity of organisms.

Learning Outcomes

Candidates should be able to:

(a) explain how cell division and enlargement lead to growth.

(b) describe the techniques for the measurement of the growth of microorganisms, plants and animals and discuss the problems of measurement.

(c) measure the growth of a chosen organism, including dry mass.

(d) distinguish between *absolute* and *relative growth rates.*

(e) recognise different types of growth curve and explain patterns of growth.

(f) explain development as a progressive series of changes, including the specialisation of cells.

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

2 Asexual Reproduction

Content

Natural and artificial means of asexual reproduction in organisms leading to genetic uniformity.

Learning Outcomes

Candidates should be able to:

(a) review the range of asexual reproduction in organisms.

(b) describe asexual reproduction using one example from each of the five kingdoms: Prokaryotae, Protoctista, Fungi, Plantae, Animalia.

(c) discuss the natural advantages and disadvantages of asexual reproduction and explain its evolutionary consequences.

(d) describe how knowledge of growth and development has been used commercially to develop methods of artificial propagation.

(e) discuss the advantages and disadvantages of cloning. (Reference to the cloning of food plants is expected but no practical details of tissue culture are required.)

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

3 Sexual Reproduction in Flowering Plants

Content

Sexual reproduction requires specialised structures for pollination.
Fertilisation produces new genetic combinations.
Changes occur after fertilisation leading to the development of the seed and fruit.

Learning Outcomes

Candidates should be able to:

(a) recognise and name the main parts of a typical simple flower.

(b) describe and explain the structural features of a named insect-pollinated and a named wind-pollinated plant.

(c) describe the mechanisms and compare the outcomes of self-pollination and cross-pollination.

(d) describe anther structure and pollen formation.

(e) describe ovule development.

(f) describe, and explain the significance of, double fertilisation in the embryo sac.

(g) describe the structural changes which occur after fertilisation leading to the development of the embryo within the seed and the ovary into the fruit.

(h) investigate embryo development experimentally by using ovules at different stages of development e.g. in shepherd's purse.

(i) describe seed structure and germination.

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

4 Sexual Reproduction in Humans

Content

Sexual reproduction in humans requires specialised cells.
Fusion of gametes produces a zygote.
Early development is dependent on maternal resources.

Learning Outcomes

Candidates should be able to:

(a) identify and name the parts of the male and female urinogenital systems.

(b) recognise and describe the microscopic structure of the ovary and testis. (Prepared slides from a small mammal may be used.)

(c) describe and explain gametogenesis.

(d) describe the structures of egg and sperm.

(e) explain how gametogenesis is controlled by hormones.

(f) describe and explain the menstrual cycle.

(g) describe the passage of sperm from the testes to the oviduct during sexual intercourse.

(h) state how and where fertilisation occurs.

(i) discuss contraception, *in vitro* fertilisation and abortion from a biological and ethical viewpoint.

(j) describe the structure of the placenta.

(k) describe and explain the roles of the placenta and the transport mechanisms involved in placental transfer.

(l) describe the functions of the amnion.

(m) discuss the effect of the actions of the mother on fetal development.

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

5 Control of Growth and Reproduction

Content

Growth and development depend on genetic and environmental factors.
Plant growth regulators in flowering plants and hormones in mammals form the basis of the control mechanisms.

Learning Outcomes

Candidates should be able to:

(a) explain the factors that control flowering in short-day and long-day plants.

(b) describe the use of plant growth regulators in fruit maturation.

(c) design and carry out an investigation to identify the major factors affecting germination.

(d) describe the reasons for, and the advantages of, seed dormancy.

(e) explain the interactions of plant growth substances in the control of seed dormancy.

(f) describe the role of hormones in the menstrual cycle, pregnancy, birth and lactation.

(g) outline the role of hormones in pre-menstrual tension, hormone replacement therapy and the menopause.

(h) outline the roles of the hypothalamus and the pituitary gland in human growth and development.

(i) describe the role of thyrotrophin releasing hormone (TRH) from the hypothalamus and thyroid stimulating hormone (TSH) from the pituitary gland in the control of thyroxine secretion.

(j) describe the role of the thyroid gland and the functions of thyroxine.

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

THE EXTENDED INVESTIGATION
PAPER 4
NOTES FOR THE GUIDANCE OF TEACHERS

General Information

The Extended Investigation must show evidence of a candidate's ability to identify an issue or problem, conduct appropriate background research and practical work, collect and analyse data, and present reasoned arguments in drawing conclusions and evaluating the data.

The time to be spent on an Investigation should be no more than 15 hours, some of which may involve private study work. The resulting account of the Investigation should be no more than 2500 words, excluding headings, tables, graphs and appendices. The Extended Investigation should be submitted for Moderation by **30 April in the year of the examination**.

The Extended Investigation should be an **individual** study, and may be **either** Laboratory/Fieldwork based **or** Work-related.

The Extended Investigation (Work-related)

It is intended that this version of the Extended Investigation should be 'applied' in nature and should arise from the stimulus provided by a short work placement, or visits. The work placement may be with industrial/commercial companies, hospitals, farms, or with professionals such as Doctors, Dentists, Vets, Pharmacists, Chiropodists, etc., whose work is related to biology in its broadest sense. It is intended that the work placement will form a valuable and integral part of the student's course. In some cases, it may be more convenient for students to make several short visits, rather than to spend longer periods of time at the establishment.

During the work placement/visits, the student should take the opportunity to look in detail at one application of biology, in the particular area of work, as well as gaining a more general knowledge/appreciation of the work being carried out. For example, a student could work on a farm and investigate the use of fertilisers by the farmer. This could lead on to investigations into the effect of fertilisers on the growth of crop plants. The effect of nitrate pollution in local water courses could also be considered. Another area of investigation on a farm could be the use of heavy machinery around the farm, and the effect that this may have on the farm environment.

The practical aspect of the work, **which must be an integral part of the Work-related Investigation,** could be workplace based, if that can be arranged. If this is not possible, practical work arising from, or leading on from, the work placement may be carried out back in a school laboratory etc., if appropriate. The latter situation may be likely to arise where students are working with Doctors, Pharmacists etc.

Teachers are reminded that they must comply with the school/college/local authority policy and procedures on work placements. OCR will take no responsibility for any injury etc. which occurs to a student during a work placement.

A Teacher's Handbook is available.

Approval

Titles and brief outlines of the proposed Extended Investigations must be submitted for approval to OCR on the Outline Proposal Forms, **at least six weeks before** the candidates are due to start work on the Investigation.

Teacher Assessment of Extended Investigations

The assessment of the Extended Investigation is based on three Skills:

A Planning
B Implementing
C Interpreting and Concluding

There are six assessment criteria for each of the three Skills. Each assessment criterion is marked on a scale of 0-2. The marks awarded should be as follows:

2: criterion completely met
1: criterion partly met
0: criterion not met at all.

Skill descriptors and assessment criteria are fully detailed on pages 44 to 47.

The marks awarded should be based on both the candidate's final written account, and on the teacher's knowledge of the work carried out by the candidate. In assigning a mark, attention should be paid to the extent of guidance needed by/given to the candidate.

The total number of raw marks available for the Extended Investigation is **36.**

Each Investigation account should be annotated to show how marks have been awarded in relation to the relevant assessment criteria. These annotations should be made at appropriate points in the margins of the text. Appropriate abbreviations or symbols may be used by the teacher to indicate the different marking criteria being assessed.

Notes on the use of statistics in Biology

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 chi-squared test. t-tests are of value in much of Biology, while the chi-squared 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 chi-squared 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 chi-squared table.

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

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

5

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

Key to symbols

*s = standard deviation
Σ = 'sum of . . .'
x = observation
$\bar{x}$ = mean
n = sample size (number of observations)

ν = 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 OCR.) Questions involving the use of a t-test or a χ^2 test may be set on Papers 1 or 3.

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

Extended Investigation

SKILL A PLANNING

ASSESSMENT CRITERION		REQUIREMENT	MAXIMUM MARK AVAILABLE
A1	APPLICATION	Knowledge of principle/theory/ model clearly explained.	2
A2	DEFINITION	Hypothesis should be testable by student. (Evidence of a prediction should be quantitative, where appropriate.)	2
A3	VARIABLES	Key variables including control variables identified.	2
A4	ORGANISATION	Plan involving a series of well-ordered steps.	2
A5	APPARATUS	Appropriate apparatus/questionnaire selected or designed and quantities of materials appropriate.	2
A6	PROCEDURES	Developed plan effective in testing the stated hypothesis.	2

Each assessment criterion is marked on a scale of 0–2

2: criterion fully met
1: criterion partly met
0: criterion not met at all.

The total raw mark available for each skill is 12.

Extended Investigation

SKILL B IMPLEMENTING

ASSESSMENT CRITERION		REQUIREMENT	MAXIMUM MARK AVAILABLE
B1	CARRYING OUT	Experimental work carried out in a careful and organised way.	2
B2	SAFETY	Sensible conduct, with concern shown for safety of self and others and/or for equipment	2
B3	MANIPULATIVE SKILLS	Apparatus used skilfully.	2
B4	OBSERVATIONS A	Accurate and detailed observations made.	2
B5	OBSERVATIONS B	Raw data/observations presented in suitable format	2
B6	PRECISION	Measurements made to the appropriate degree of precision.	2

Each assessment criterion is marked on a scale of 0–2

2: criterion fully met
1: criterion partly met
0: criterion not met at all.

The total raw mark available for each skill is 12.

Extended Investigation

SKILL C INTERPRETING AND CONCLUDING

ASSESSMENT CRITERION		REQUIREMENT	MAXIMUM MARK AVAILABLE
C1	**PROCESSING**	Numerical processing of results, including statistical analysis.	2
C2	**RELIABILITY**	Reliability and accuracy of own experimental data assessed. Limitations of apparatus used and/or sources of error in techniques fully explained.	2
C3	**MODIFICATION**	Modifications suggested to procedures, or justification offered for no modification.	2
C4	**INTERPRETATION**	Knowledge of biological principles/ theory used to explain trends and patterns of own results including anomalous results, if appropriate.	2
C5	**CONCLUSION**	Full conclusions drawn **supported by reference to data**.	2
C6	**COMMUNICATION**	Results communicated clearly (tabulation, line graphs, histograms and continuous prose as appropriate).	2

Each assessment criterion is marked on a scale of 0–2

2: criterion fully met
1: criterion partly met
0: criterion not met at all.

The total raw mark available for each skill is 12.

Each Investigation account should be annotated to show how marks have been awarded in relation to the relevant assessment criteria. These annotations should be made at appropriate points in the margins of the text. Appropriate abbreviations or symbols may be used by the teacher to indicate the different marking criteria being assessed.

Moderation

(i) *Internal Moderation*

Where more than one teacher in a Centre is involved in marking the Extended Investigations, arrangements must be made within the Centre to ensure consistent application of the assessment criteria. A report of these arrangements must be included with the work sent to OCR for external moderation.

Internal moderation is essential to produce a single valid order of merit for the entry from the Centre.

(ii) *External Moderation*

1. A Coursework Cover Sheet should be completed for each candidate, and attached to each candidate's account of the Extended Investigation, before submission for Moderation.

2. The Mark sheet (MS1) should be completed with the assessment totals for all candidates and dispatched to OCR according to the instructions received from OCR.

3. If there are 20 or fewer candidates from the Centre, the written accounts of the Extended Investigation of **all** the candidates should be submitted for Moderation.

4. If there are more than 20 candidates from a Centre, the written accounts of the Extended Investigation of **20 candidates** should be submitted for Moderation. The 20 candidates should represent the full mark range, as evenly spaced as possible, and should include candidates from each teaching group, if appropriate.

The work of additional candidates may be requested in order to arrive at a decision regarding the standard of work.

Authentication

Teachers must be able to supply evidence of their continuing supervision of the work. Where the nature of the subject requires candidates to undertake assessed coursework activities outside the Centre, a proportion of the work must take place under direct supervision. The proportion must be sufficient to enable the teacher to authenticate each candidate's work with confidence.

Safety in the Laboratory

Responsibility for safety matters rests with Centres. The attention of teachers and students is drawn to the guidelines issued by the DFE and by LEAs ,with regard to the use of animals in experiments.

Attention is drawn to the following:

(*a*) the requirements, as published in October 1989, of COSHH (the Committee on Safety of Substances Hazardous to Health);

(*b*) *Safe Practices in Chemical Laboratories,* the Royal Society of Chemistry, 1989;

(*c*) *Safety in Science Laboratories,* DES Safety Series, 2, HMSO, 1976;

(*d*) *Hazards in the Chemical Laboratory,* ed. L. Bretherick, The Royal Society of Chemistry, 4th ed., 1986;

(*e*) *Safeguards in the School Laboratory* ASE, 9th ed., 1988;

(f) *Hazcards,* as published by CLEAPSS Development Group, Brunel University, Uxbridge UB8 3PH;

(*g*) *Animals and Plants in Schools: Legal Aspects,* DES Administrative Memorandum No. 3/90.

THE EXTENDED INVESTIGATION
PAPER 4
NOTES FOR THE GUIDANCE OF CANDIDATES

The Extended Investigation should be an individual study, and should be **either** Laboratory/Field-work based, **or** Work-related. Each completed Investigation should be no more than 2500 words in length, excluding headings, tables, graphs and appendices. It should be submitted for Moderation by **30 April in the year of the examination.**

Accounts of the Extended Investigation should consist of the following clearly identified sections:

1. A clearly stated **title,** an **abstract** and a **contents list.**

2. An **introduction** which should briefly put the investigation in context and 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 **bibliography** or **footnotes** referencing the researched information.

9. A list of **acknowledgements** indicating the source and extent of any help that has been received.

Pages in the written accounts must be numbered, and the Investigation should be submitted for external moderation in a light paper folder (**not** a heavy ring binder).

INTERNAL ASSESSMENT OF EXPERIMENTAL SKILL A
PAPER 6
NOTES FOR THE GUIDANCE OF TEACHERS

Introduction

This paper is **additional** to Paper 5 (practical examination) and **must be taken if candidates have been entered for the practical examination.**

The scheme detailed below is intended to provide guidance for teachers in marking the assessment of Experimental Skill **A**. It is not intended that the scheme should exert an undue influence on the methods of teaching or provide a constraint on the practical work undertaken by candidates. Rather, the skill 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 assessments may be carried out any time during the course using suitable practical activities which are related to, or are part of, the teaching of the course. It is expected that students will have had opportunities to acquire experience and develop the relevant skill before assessment takes place.

At whatever stage the assessments are carried out, the standards applied must be those of A level, i.e. those expected at the end of the course, as exemplified in the assessment criteria. Students should be informed when an assessment is to take place.

The assessed practical coursework must be annotated to show how the marks have been awarded in relation to the relevant assessment criteria for Skill A.

The writing of comments on students' work can provide a means of dialogue and feedback between teacher and student and a means of communication between teachers during internal moderation of coursework. The main purpose of writing comments on candidates' coursework is, however, to provide a means of communication between teacher and coursework moderator, showing where marks have been awarded and why.

For written coursework, annotations should be made at appropriate points in the margins of the text. The annotations should indicate where achievement against a specified assessment criterion for a particular sub-Skill has been noted. Appropriate abbreviations or symbols may be used to indicate the marking criterion concerned.

The annotations should also indicate the mark to be awarded for each sub-Skill.

A Teacher's Handbook is available.

Teacher-assessment of Experimental Skill A

There are six assessment criteria for the skill and each assessment criterion is marked on a scale of 0-2.

2: criterion completely met;
1: criterion partly met;
0: criterion not met at all.

The total raw mark available for the assessment Skill **A** is 12.

Centres will be required to submit **one score out of 12 for Skill A.**

The marks awarded should be based on both the final written work and the teacher's knowledge of the work carried out by the student. In assigning a mark, attention should be paid to the extent of guidance needed by/given to the student. A form for recording the marks for each Skill assessment will be provided by OCR.

Students should be assessed on the Skill on a **minimum** of 2 occasions and the best mark for the Skill submitted.

A Handbook for Teachers is available.

Suitability of Coursework

It is essential that all teachers assessing candidates' practical work should be familiar with the requirements of the syllabus.

If teachers in a Centre are not certain that their proposed practical work will satisfy the syllabus requirements, then they should write to the relevant OCR Subject Officer to seek clarification **well before the proposed work is due to be carried out.**

Titles of suitable practical exercises for the assessment of Skill **A** are printed in the Handbook for Teachers.

Experimental Skills

SKILL A PLANNING

ASSESSMENT CRITERION		REQUIREMENT	MAXIMUM MARK AVAILABLE
A1	APPLICATION	Knowledge of principle/theory/ model clearly explained.	2
A2	DEFINITION	Hypothesis should be testable by student. (Evidence of a prediction should be quantitative, where appropriate.)	2
A3	VARIABLES	Key variables including control variables identified.	2
A4	ORGANISATION	Plan involving a series of well-ordered steps.	2
A5	APPARATUS	Appropriate apparatus/questionnaire selected or designed and quantities of materials appropriate.	2
A6	PROCEDURES	Developed plan effective in testing the stated hypothesis.	2

Each assessment criterion is marked on a scale of 0–2

2: criterion fully met
1: criterion partly met
0: criterion not met at all.

The total raw mark available for each skill is 12.

Safety in the Laboratory

Responsibility for safety matters rests with Centres. The attention of teachers and students is drawn to the guidelines issued by the DFE and by LEAs with regard to the use of animals in experiments.

Attention is drawn to the following:

(a) the requirements, as published in October 1989, of COSHH (the Committee on Safety of Substances Hazardous to Health);

(b) *Safe Practices in Chemical Laboratories,* the Royal Society of Chemistry, 1989;

(c) *Safety in Science Laboratories,* DES Safety Series, 2, HMSO, 1976;

(d) *Hazards in the Chemical Laboratory,* ed. L. Bretherick, The Royal Society of Chemistry, 4th ed., 1986;

(e) *Safeguards in the School Laboratory,* ASE, 9th ed., 1988;

(f) *Hazcards,* as published by CLEAPSS Development Group, Brunel University, Uxbridge UB8 3PH;

(g) *Animals and Plants in Schools: Legal Aspects,* DES Administrative Memorandum No. 3/90.

Moderation

(i) *Internal Moderation*

Where more than one teacher in a Centre is involved in internal assessment, arrangements must be made within the Centre to ensure consistent application of the assessment criteria. A report of these arrangements must be included with the work sent to OCR for external moderation.

Internal moderation is essential to produce a single valid order of merit for the entry from the Centre.

(ii) *External Moderation*

Teachers should retain all work used as a basis for the assessment.

The work should be submitted for moderation by **30 April in the year of the examination.**

Each Centre will be required to send the following information about the assessment when the work is sent for Moderation:

1. A summary which identifies the activities used for assessment. This must show how the task was presented to candidates, including any worksheets or other documentation issued to candidates, and what marking criteria were applied. A form which should be attached to each piece of any candidate's work will be provided by OCR and may be photocopied.
2. One copy of the Mark Sheet (MS1) should be completed with the assessment totals for all candidates.
3. If there are 20 or fewer candidates from the Centre, the written work **contributing to the assessment total** of **all** the candidates should be submitted for moderation.
4. If there are more than 20 candidates from a Centre, then the written work **contributing to the assessment total** of **20** candidates should be sent for Moderation. The 20 candidates selected should represent the full mark range, as evenly spaced as possible, and should include candidates from each teaching group.

The work of additional candidates may be requested in order to arrive at a decision regarding the standard of work.

Authentication

Teachers must be able to supply evidence of their continuing supervision of the work. Where the nature of the subject requires candidates to undertake assessed coursework activities outside the Centre, a proportion of the work must take place under direct supervision. The proportion must be sufficient to enable the teacher to authenticate each candidate's work with confidence.

Administration and Regulations

Schools must indicate their intention to enter candidates for Paper 6 using the **early Provisional Entries Estimate Form (PEIA)** which is received in schools in the **September of the first year of the course.**

Paper 6 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 86.

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 OCR, should not be given to the students.

INTERNAL ASSESSMENT OF EXPERIMENTAL SKILLS PAPER 9
NOTES FOR THE GUIDANCE OF TEACHERS

Introduction

The scheme detailed below is intended to provide guidance for teachers in marking the assessment of the Experimental Skills, 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 assessments may be carried out any time during the course using suitable practical activities which are related to, or are part of, the teaching of the course. It is expected that students will have had opportunities to acquire experience and develop the relevant skills before assessment takes place.

At whatever stage assessments are carried out, the standards applied must be those of A level, i.e. those expected at the end of the course, as exemplified in the assessment criteria. Students should be informed when an assessment is to take place.

Each piece of assessed practical coursework must be annotated to show how the marks have been awarded in relation to the relevant assessment criteria.

The writing of comments on students' work can provide a means of dialogue and feedback between teacher and student, and a means of communication between teachers during internal moderation of coursework. The main purpose of writing comments on candidates' coursework is, however, to provide a means of communication between teacher and coursework moderator, showing where marks have been awarded and why.

For written coursework, annotations should be made at appropriate points in the margins of the text. The annotations should indicate where achievement against a specified assessment criterion for a particular skill has been noted. Appropriate abbreviations or symbols may be used to indicate the marking criterion concerned.

The annotations should also indicate the mark to be awarded for each skill.

A Teacher's Handbook is available.

Teacher-assessment of the Experimental Skills

The Experimental Skills to be assessed are given below:

A Planning
B Implementing
C Interpreting and Concluding

There are six assessment criteria for each skill and each assessment criterion is marked on a scale of 0-2.

2: criterion completely met;
1: criterion partly met;
0: criterion not met at all.

The three skills carry equal weighting.

The total raw mark available for the assessment of each individual Skill is 12.

Centres will be required to submit **one score out of 12 for Skill A, one score out of 12 for Skill B and one score out of 12 for Skill C.**

It is expected that Skill **A** will be assessed **separately** from Skills **B** and **C**. Within each Skill area, there are a number of sub-Skills. For skills **B** and **C**, teachers are advised **to use more than one practical exercise,** in order to assess all the sub-Skills.

The marks awarded should be based on both the final written work and the teacher's knowledge of the work carried out by the student. In assigning a mark, attention should be paid to the extent of guidance needed by/given to the student. A form for recording the marks for each Skill assessment will be provided by OCR.

Students should be assessed on each Skill, or sub-Skill, on a **minimum** of 2 occasions and the best mark for each Skill submitted.

A Handbook for Teachers is available.

Suitability of Coursework

It is essential that all teachers assessing candidates' practical work should be familiar with the requirements of the syllabus.

If teachers in a Centre are not certain that their proposed practical work will satisfy the syllabus requirements, then they should write to the relevant OCR Subject Officer to seek clarification **well before the proposed work is due to be carried out.**

Titles of suitable practical exercises for the assessment of the Skills are printed in the Handbook for Teachers.

Experimental Skills

SKILL A PLANNING

ASSESSMENT CRITERION		REQUIREMENT	MAXIMUM MARK AVAILABLE
A1	APPLICATION	Knowledge of principle/theory/ model clearly explained.	2
A2	DEFINITION	Hypothesis should be testable by student. (Evidence of a prediction should be quantitative, where appropriate.)	2
A3	VARIABLES	Key variables including control variables identified.	2
A4	ORGANISATION	Plan involving a series of well-ordered steps.	2
A5	APPARATUS	Appropriate apparatus/questionnaire selected or designed and quantities of materials appropriate.	2
A6	PROCEDURES	Developed plan effective in testing the stated hypothesis.	2

Each assessment criterion is marked on a scale of 0–2

2: criterion fully met
1: criterion partly met
0: criterion not met at all.

The total raw mark available for each skill is 12.

Experimental Skills

SKILL B IMPLEMENTING

ASSESSMENT CRITERION		REQUIREMENT	MAXIMUM MARK AVAILABLE
B1	CARRYING OUT	Experimental procedure carried out in a careful and organised way.	2
B2	SAFETY	Sensible conduct, with concern shown for safety of self and others and/or for equipment	2
B3	MANIPULATIVE SKILLS	Apparatus used skilfully.	2
B4	OBSERVATIONS A	Accurate and detailed LP **and** HP annotated drawings made.	2
B5	OBSERVATIONS B	Raw data/observations presented in suitable format	2
B6	PRECISION	Measurements made are accurate and to the appropriate degree of precision.	2

Each assessment criterion is marked on a scale of 0–2

2: criterion fully met
1: criterion partly met
0: criterion not met at all.

The total raw mark available for each skill is 12.

Experimental Skills

SKILL C INTERPRETING AND CONCLUDING

ASSESSMENT CRITERION		REQUIREMENT	MAXIMUM MARK AVAILABLE
C1	PROCESSING	Numerical processing of results, including statistical analysis.	2
C2	RELIABILITY	Reliability and accuracy of own experimental data assessed. Limitations of apparatus and/or sources of error in techniques fully explained.	2
C3	MODIFICATION	Modifications suggested to procedures, or justification offered for no modification.	2
C4	INTERPRETATION	Knowledge of biological principles/ theory used to explain trends and patterns of own results including anomalous results, if appropriate.	2
C5	CONCLUSION	Full conclusions drawn **supported by reference to data**.	2
C6	COMMUNICATION	Results communicated clearly and appropriately by graphs.	2

Each assessment criterion is marked on a scale of 0–2

2: criterion fully met
1: criterion partly met
0: criterion not met at all.

The total raw mark available for each skill is 12.

Safety in the Laboratory

Responsibility for safety matters rests with Centres. The attention of teachers and students is drawn to the guidelines issued by the DFE and by LEAs with regard to the use of animals in experiments.

Attention is drawn to the following:

(a) the requirements, as published in October 1989, of COSHH (the Committee on Safety of Substances Hazardous to Health);

(b) *Safe Practices in Chemical Laboratories,* the Royal Society of Chemistry, 1989;

(c) *Safety in Science Laboratories,* DES Safety Series, 2, HMSO, 1976;

(d) *Hazards in the Chemical Laboratory,* ed. L. Bretherick, The Royal Society of Chemistry, 4th ed., 1986;

(e) *Safeguards in the School Laboratory,* ASE, 9th ed., 1988;

(f) *Hazcards,* as published by CLEAPSS Development Group, Brunel University, Uxbridge UB8 3PH;

(g) *Animals and Plants in Schools: Legal Aspects,* DES Administrative Memorandum No. 3/90.

Moderation

(*i*) *Internal Moderation*

Where more than one teacher in a Centre is involved in internal assessment, arrangements must be made within the Centre to ensure consistent application of the assessment criteria. A report of these arrangements must be included with the work sent to OCR for external moderation.

Internal moderation is essential to produce a single valid order of merit for the entry from the Centre.

(*ii*) *External Moderation*

Teachers should retain all work used as a basis for assessment.

The work should be submitted for Moderation by **30 April in the year of the examination.**

Each Centre will be required to send the following information about the assessment when the work is sent for Moderation:

1. A summary which identifies all of the activities used for assessment. This must show how the task was presented to candidates, including any worksheets or other documentation issued to candidates, and what marking criteria were applied. A form which should be attached to each piece of any candidate's work will be provided by OCR and may be photocopied.
2. One copy of the Mark Sheet (MS1) should be completed with the assessment totals for all candidates.
3. If there are 20 or fewer candidates from the Centre, the written work **contributing to the assessment totals** of **all** the candidates should be submitted for moderation.
4. If there are more than 20 candidates from a Centre, then the written work **contributing to the assessment totals** of **20** candidates should be sent for Moderation. The 20 candidates selected should represent the full mark range, as evenly spaced as possible, and should include candidates from each teaching group.

The work of additional candidates may be requested in order to arrive at a decision regarding the standard of work.

Authentication

Teachers must be able to supply evidence of their continuing supervision of the work. Where the nature of the subject requires candidates to undertake assessed coursework activities outside the Centre, a proportion of the work must take place under direct supervision. The proportion must be sufficient to enable the teacher to authenticate each candidate's work with confidence.

Administration and Regulations

Schools must indicate their intention to enter candidates for Paper 9 using the **early Provisional Entries Estimate Form (PEIA)** 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 OCR, should not be given to the students.

Glossary of terms used in science papers

It is hoped that the glossary (which is relevant only to Science subjects) will prove helpful to candidates as a guide, i.e. it is neither exhaustive nor definitive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context.

1. *Define (the term(s)...)* is intended literally, only a formal statement or equivalent paraphrase being required.

2. *What do you understand by/What is meant by (the term(s)...)* normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.

3. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can readily be obtained 'by inspection'.

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

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

6. *Describe* requires the candidate to state in words (using diagrams, where appropriate) the main points of this topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena.

   In other contexts, *describe and give an account* of should be interpreted more generally, i.e. the candidate has greater discretion about the nature and the organisation of the material to be included in the answer. *Describe and explain* may be coupled in a similar way to *state and explain.*

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

8. *Outline* implies brevity, i.e. restricting the answer to giving essentials.

9. *Predict* or *deduce* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an early part of the question.

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

11. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer (e.g. in chemistry, two or more substances may satisfy the given conditions describing an 'unknown'), or to imply that candidates are expected to apply their general knowledge to a 'novel' situation, one that may be formally 'not in the syllabus'.

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

13. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.

14. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or mass, using a balance.

15. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula, e.g. relative molecular mass.

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

17. *Sketch,* when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, but candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value.
In diagrams, sketch implies that a simple, freehand drawing is acceptable: nevertheless, care should be taken over proportions and the clear exposition of important details.

Special Note

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.