



Singapore Examinations and Assessment Board



Singapore–Cambridge General Certificate of Education Advanced Level Higher 3 (2027)

Biology (Syllabus 9816)

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PREAMBLE

The H3 Biology syllabus is designed to build on and extend the knowledge, understanding and skills acquired from the H2 Biology syllabus. It caters to students of strong ability and keen interest in biology, and is designed with a strong emphasis on independent and self-directed learning. The H3 Biology syllabus is meant to provide a comprehensive understanding of the subject through depth and rigour, not only for students pursuing further studies in the biology-related fields, but also for those who would find the knowledge and understanding useful in future.

INTRODUCTION

The value of learning H2 and H3 Biology ultimately hinges on the development of a scientific mind and disposition while addressing the broader questions of what life is and how life is sustained. The Science Curriculum Framework developed by the Ministry of Education elaborates on the development of the scientific mind and disposition. Through the study of the H2 and H3 Biology courses, students will be prepared for life science-related courses at university and, consequently, careers that are related to this field.

AIMS

The *Aims* of a course based on this syllabus should be to:

- 1 provide students with an experience that deepens their knowledge and skills of biology, and fosters attitudes necessary for further studies in related fields
- 2 develop in students an appreciation of the practice, value and rigour of biology as a discipline
- 3 develop in students the skills to think deeply, laterally and critically about biological issues, so that they can critically analyse what they have read and respond through writing well-structured arguments that integrate knowledge and skills acquired from different areas of biology
- 4 develop in students the skills needed for effective scientific communication to different audiences through a range of styles, modes and tools.

PRACTICES OF SCIENCE

The H3 syllabus allows for deeper development of the *Practices of Science* (POS) detailed in the H2 syllabus.

The *Practices of Science* comprise three components:

1 Demonstrating Ways of Thinking and Doing (WOTD)

The Ways of Thinking and Doing in Science illustrate a set of established procedures and practices associated with scientific inquiry to gather evidence and test ideas on how the natural world works. There are three broad, iterative domains of scientific activity: investigating, evaluating and reasoning, and developing explanations and solutions.

- 1.1 Posing questions and defining problems
- 1.2 Designing investigations
- 1.3 Conducting experiments and testing solutions
- 1.4 Analysing and interpreting data
- 1.5 Communicating, evaluating and defending ideas with evidence
- 1.6 Making informed decisions and taking responsible actions
- 1.7 Using and developing models¹
- 1.8 Constructing explanations and designing solutions

2 Understanding the Nature of Scientific Knowledge (NOS)

Science is an epistemic endeavour to build a better understanding of reality.

- 2.1 Science is an evidence-based, model-building enterprise to understand the real world.
- 2.2 Science assumes natural causes, order and consistency in natural systems.
- 2.3 Scientific knowledge is generated through established procedures and critical debate.
- 2.4 Scientific knowledge is reliable, durable and open to change in light of new evidence.

3 Relating Science-Technology-Society-Environment (STSE)

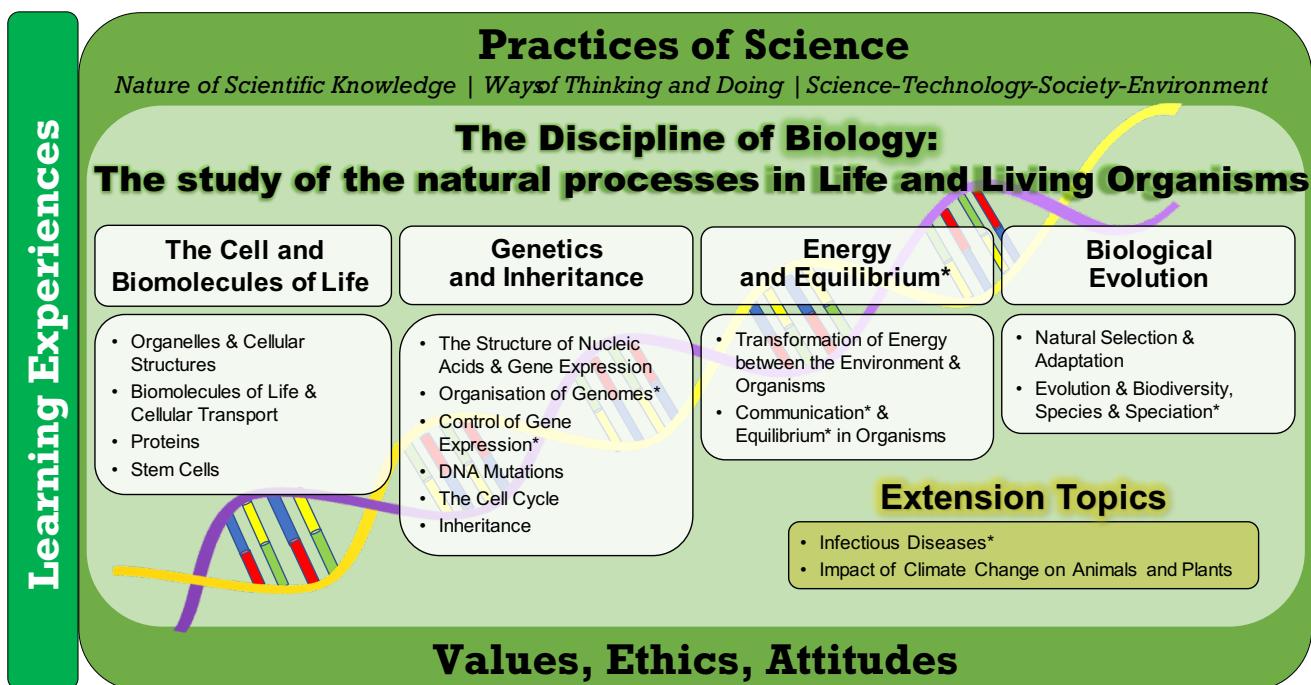
Science is not done completely independently of the other spheres of human activity. The relationships and connections to these areas are important as students learn science in context.

- 3.1 There are risks and benefits associated with the applications of science in society.
- 3.2 Applications of science often have ethical, social, economic and environmental implications.
- 3.3 Applications of new scientific discoveries often drive technological advancements while advances in technology enable scientists to make new or deeper inquiry.

¹ A model is a representation of an idea, an object, a process or a system that is used to describe and explain phenomena that cannot be experienced directly. Models exist in different forms from the concrete, such as physical, scale models to abstract representations, such as diagrams or mathematical expressions. The use of models involves the understanding that all models contain approximations and assumptions limiting their validity and predictive power.

CURRICULUM FRAMEWORK

The A-Level Biology Curriculum Framework (Figure 1) guides the design and implementation of the A-level Biology curriculum.



* in H2 and H3 Biology only

Figure 1: A-Level Biology Curriculum Framework

The *Practices of Science* highlight the ways of thinking and doing that are inherent in the scientific approach, with the aim of equipping students with the understanding, skills, and attitudes shared by the scientific disciplines, including an appropriate approach to ethical issues.

The *Values, Ethics, Attitudes* undergird the study of science and the use of related knowledge and skills to make a positive contribution to humanity.

The *Learning Experiences (LEs)*² refer to a range of learning opportunities that enhance students' learning of Biology. Real-world contexts can help illustrate the application of Biology concepts and bring the subject to life. These *LEs* would include experimental (practical work) activities and ICT tools that can be used to build students' understanding.

The *Disciplinary Content* of the Biology syllabuses is organised around four *Core Ideas* of Biology. Besides the *Core Ideas*, the H3 Biology syllabus features two *Extension Topics*: (A) Infectious Diseases, and (B) Impact of Climate Change on Animals and Plants. The two *Extension Topics* are based on important emerging biological issues impacting both the local and global contexts. They require students to demonstrate assimilation of the *Core Ideas* and extend their knowledge and understanding to real-world challenges. Furthermore, *Extension Topics* will equip students with the necessary knowledge and process skills to make informed decisions about scientific issues.

Through H3 Biology, students acquire the skills for thinking deeply, laterally and critically in the areas of biology; the ability to critically analyse what they have read and respond through writing well-structured arguments that integrate knowledge and skills acquired from different areas of biology; and the skills for effective communication to different audiences through a range of styles, modes and tools.

Students are expected to study all four *Core Ideas* and both the *Extension Topics*.

² Learning Experiences can be found in the Teaching and Learning Syllabus.

ASSESSMENT OBJECTIVES

The Assessment Objectives listed below reflect those parts of the *Aims and Practices of Science* that will be assessed.

A Knowledge with understanding

Candidates should be able to demonstrate knowledge with understanding in relation to:

- 1 scientific phenomena, facts, laws, definitions, concepts and theories
- 2 scientific vocabulary, terminology and conventions (including symbols, quantities and units)
- 3 scientific instruments and apparatus, including techniques of operation and aspects of safety
- 4 scientific quantities and their determination
- 5 scientific and technological applications with their social, economic and environmental implications.

The syllabus content defines the factual knowledge that candidates may be required to recall and explain. Questions testing these objectives will often begin with one of the following words: *define, state, name, describe, explain or outline* (see the *Glossary of Terms*).

B Handling, applying and evaluating information

Candidates should be able (in words or by using symbolic, graphical and numerical forms of presentation) to:

- 1 locate, select, organise, interpret and present information from a variety of sources
- 2 handle information, distinguishing the relevant from the extraneous
- 3 manipulate numerical and other data and translate information from one form to another
- 4 present reasoned explanations for phenomena, patterns, trends and relationships
- 5 make comparisons that may include the identification of similarities and differences
- 6 analyse and evaluate information to identify patterns, report trends, draw inferences, report conclusions and construct arguments
- 7 justify decisions, make predictions and propose hypotheses
- 8 apply knowledge, including principles, to novel situations
- 9 use skills, knowledge and understanding from different areas of Biology to solve problems
- 10 organise and present information, ideas and arguments clearly and coherently, using appropriate language.

These Assessment Objectives above cannot be precisely specified in the syllabus content because questions testing such skills are often based on information which is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts that are within the syllabus and apply them in a logical, reasoned or deductive manner to a novel situation. Questions testing these objectives will often begin with one of the following words: *discuss, predict, suggest, calculate or determine* (see the *Glossary of Terms*).

SCHEME OF ASSESSMENT

Paper 1 (2 h 30 min, 75 marks)

This paper will consist of two sections, as follows:

Section A (50 marks) will comprise one compulsory stimulus-based question (25 marks) that may consist of a variable number of structured subparts; and one compulsory free-response question (25 marks), with no subparts. For the free-response question, the quality of scientific argumentation and written communication will be given a percentage of the marks available.

Section B (25 marks) will comprise two free-response questions, from which candidates will choose **one**. The quality of scientific argumentation and written communication will be given a percentage of the marks available.

Questions in both sections may be set on any area of the H3 and H2 syllabuses, and may require candidates to use material from different areas of the syllabuses within a single answer. Marks will also be available for evidence shown for relevant reading around the subject.

Weighting of Assessment Objectives

Assessment Objective		Weighting (%)
A	Knowledge with understanding	25
B	Handling, applying and evaluating information	75

ADDITIONAL INFORMATION

Modern biological sciences draw extensively on concepts from the physical sciences. It is desirable therefore that, by the end of the course, students should have knowledge of the following topics, sufficient to aid understanding of biological systems. No questions will be set directly on them except where relevant to the assessment of a Learning Outcome.

- 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

Nomenclature

Candidates will be expected to be familiar with the nomenclature used in the syllabus. The proposals in '*Signs, Symbols and Systematics*' (The Association for Science Education Companion to 16–19 Science, 2000) and the recommendations on terms, units and symbols in '*Biological Nomenclature*' (2009) published by the Institute of Biology, in conjunction with the ASE, will generally be adopted although the traditional names sulfate, sulfite, nitrate, nitrite, sulfurous acid and nitrous acid will be used in question papers. Sulfur (and all compounds of sulfur) will be spelt with f (not with ph) in question papers. However, candidates can use either spelling in their answers.

Required Subject Combinations

Candidates should simultaneously offer H2 Biology.

Units and Significant Figures

Candidates should be aware that misuse of units and/or significant figures, e.g. 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.

STRUCTURE OF SYLLABUS

Topics and concepts relevant to the learning of H3 Biology are built upon, and to a large extent have been covered in, the prerequisite subject of H2 Biology. Familiarity with these topics and concepts will facilitate the learning of H3 Biology.

Additional content to be covered for the H3 syllabus is organised into four *Core Ideas* and two *Extension Topics*, which correspond to those in the syllabus for H2 Biology.

The Learning Outcomes list the specific content of the H3 syllabus. H2 Learning Outcomes are not listed but are all assessable as part of the H3 syllabus.

The syllabus is divided into two parts: *Core Ideas* and *Extension Topics*, to be studied by all candidates.

I Core Ideas. There are **4 Core Ideas**:

- 1 The Cell and Biomolecules of Life
- 2 Genetics and Inheritance
- 3 Energy and Equilibrium
- 4 Biological Evolution.

II Extension Topic. There are **2 Extension Topics**:

- A Infectious Diseases
- B Impact of Climate Change on Animals and Plants.

I CORE IDEAS

1 The Cell and Biomolecules of Life

Content

- The cell theory
- Outline functions of membrane systems and organelles in cells
- The fluid mosaic model
- Cell differentiation
- Protein modification

Learning Outcomes

Candidates should be able to:

- (a) describe how the fluid mosaic model of the cell membrane has developed to the current understanding
- (b) describe the basic characteristics of:
 - i prions (including morphology and replication)
 - ii Fungi (including the morphology and life cycle of yeasts and filamentous fungi)
 - iii Protoctista (including algae)
- (c) explain the following terms and discuss the extent to which each conforms to the cell theory:
 - i acellularity (including prions and viruses)
 - ii multinucleation (including hyphae of filamentous fungi)
 - iii endosymbiosis (including endosymbiotic origin of eukaryotes)
- (d) justify the need for cell differentiation in multicellular organisms
- (e) describe protein binding sites and protein subunits in producing large protein and glycoprotein molecules (including haemoglobin, immunoglobulin and prokaryotic RNA polymerase)
- (f) explain, with examples, how protein modification (including cleavage, phosphorylation and glycosylation) confer new capabilities
- (g) discuss and explain why proteins are able to recognise and bind to highly diverse molecules, with reference to the properties and shapes of their surfaces and clefts that allow highly complementary interactions
- (h) discuss how a living eukaryotic cell regulates thousands of enzymes.

Use the knowledge gained in this section in new situations or to solve related problems.

2 Genetics and Inheritance

Content

- Procedures for cloning genes
- The structure and role of ribozymes
- Techniques in genetic engineering
- Epigenetics

Learning Outcomes

Candidates should be able to:

- (a) discuss how mature cells can be returned to a stem cell state
- (b) explain that genetic engineering involves the insertion of a gene, obtained either by synthesis or by extraction from an organism, into another organism (of the same or different species), such that the receiving organism expresses the gene product
- (c) explain the roles of restriction endonucleases, reverse transcriptase and ligases in genetic engineering
- (d) outline the procedures for cloning a eukaryotic gene in a bacterial plasmid and describe the properties of plasmids that allow them to be used as DNA cloning vectors
- (e) explain how eukaryotic genes are cloned using *E. coli* cells to produce eukaryotic proteins
- (f) explain the structure and roles of ribozymes and their potential role in genetic engineering (including novel peptide synthesis and modifications)
- (g) evaluate the significance of genetic engineering to the world and humanity (including food sustainability for a rapidly growing population, disease treatment and drug design)
- (h) explain that epigenetics (including DNA methylation, histone modification and chromatin remodelling) is a process that affects the expression of specific genes, without involving a change in DNA sequence
- (i) discuss how epigenetics has contributed to the study of genetics and heredity.

Use the knowledge gained in this section in new situations or to solve related problems.

3 Energy and Equilibrium

Content

- C₃, C₄, CAM plants and algae
- Nervous system
- Control and feedback mechanisms
- Communication systems in organisms

Learning Outcomes

Candidates should be able to:

- (a) explain how the anatomy and physiology of the leaves of C₄ plants, such as maize and sorghum, are adapted to minimise photorespiration and to allow high rates of carbon fixation at high temperatures in terms of:
 - i the spatial separation of initial carbon fixation from the light-dependent stage (biochemical details of the C₄ pathway are required in outline only)
 - ii the high optimum temperatures of the enzymes involved
- (b) discuss and compare the importance in mitigating global warming of photosynthetic carbon fixation by C₃ plants, C₄ plants, CAM plants and algae, including those in reef-building corals
- (c) explain how the physiology of the leaves of CAM plants is adapted to minimise photorespiration and to allow photosynthesis while minimising water loss by transpiration, in terms of:
 - i the temporal separation of initial carbon fixation from the light-dependent stage (biochemical details of the CAM pathway are required in outline only)
 - ii stomatal opening during the night
- (d) explain, with reference to a range of well-supported hypotheses, the changes in atmospheric oxygen concentration during the evolution of life on Earth and evaluate the importance of these changes to evolution
- (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 Ca²⁺ ions
- (g) explain the need for control in organised systems and explain the principles of homeostasis in terms of receptors, effectors and negative feedback
- (h) explain the need for different communication systems within organisms.

Use the knowledge gained in this section in new situations or to solve related problems.

4 Biological Evolution

Content

- Adaptive radiation and ring species
- Polyploidy, hybridisation and introgression in evolution

Learning Outcomes

Candidates should be able to:

- (a) explain, with examples, sexual selection and its significance for evolution
- (b) explain, with examples, the evolutionary concepts of adaptive radiation and ring species
- (c) discuss the contributions of polyploidy, hybridisation and introgression in evolution and their implications for reconstructing phylogenies
- (d) explain the significance of biomolecules, and the biochemical processes through which they are synthesised, to the understanding of evolution (biomolecules to include carbohydrates, lipids, proteins and nucleic acids).

Use the knowledge gained in this section in new situations or to solve related problems.

II EXTENSION TOPIC**A Infectious Diseases****Content**

- The immune system – adaptive and innate
- Importance of microbiota to human health
- Factors that could result in a pandemic

Learning Outcomes

Candidates should be able to:

- (a) explain why specific (adaptive) and non-specific (innate) immunity can be both mutually exclusive and interdependent in the protection against pathogens
- (b) explain how immunological self-tolerance ensures that B lymphocytes and T lymphocytes do not normally attack host cells that are functioning correctly
- (c) explain why the human microbiota is important for our health
- (d) explain the factors affecting the probability that a pandemic will occur, including sanitation, water supply, food, climate, large-scale movements of people, evolution of new strains of virulent pathogens and development of drug resistance.

Use the knowledge gained in this section in new situations or to solve related problems.

B Impact of Climate Change on Animals and Plants**Content**

- Effects of climate change on the environment, plants and animals
- Actions to mitigate climate change
- How animal and plant species respond to climate change

Learning Outcomes

Candidates should be able to:

- (a) discuss how humans are responding to mitigate climate change, including biological measures (such as tree planting and developing drought-resistant varieties of crops) and lifestyle changes (such as reducing use of cars and consumption of meat)
- (b) discuss, with examples, how animal and plant species can adjust and adapt to climate change, and the possible consequences of climate change for ecosystems and the organisms within them in the longer term
- (c) discuss the impact of humans on the environment since the start of the Holocene and how this impact may be measured, including the concepts of biocapacity and ecological footprint.

Use the knowledge gained in this section in new situations or to solve related problems.

MATHEMATICAL REQUIREMENTS

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, and (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 R_o value, Hardy–Weinberg equation ($p^2 + 2pq + q^2 = 1$), t - and chi-squared tests.

Notes on the Use of Statistics in Biology

Candidates should know how to apply a t -test and a 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 or what the symbols stand for. 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.

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

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

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

Key to symbols

s^* = standard deviation Σ = ‘sum of’ \bar{x} = mean

n = sample size (number of observations) x = observation

v = degrees of freedom O = observed ‘value’

E = expected ‘value’ c = number of classes

* Candidates should note that on some calculators the symbol σ may appear instead 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.) Questions involving the use of a t -test or χ^2 test may be set but detailed computation will not be required.

Calculators

Any calculator used must be on the Singapore Examinations and Assessment Board list of approved calculators.

TEXTBOOKS AND REFERENCES

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GLOSSARY OF TERMS

It is hoped that the glossary (which is relevant only to science subjects) will prove helpful to candidates as a guide; 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 *Analyse* is a context-specific term involving the identification of the constituent parts of a complex situation or result, an assessment of their individual implications and a consideration of how these relate to one another and to scientific knowledge and understanding. Analysis may require further processing of mathematical data to reveal underlying trends and patterns.
- 2 *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.
- 3 *Classify* requires candidates to group things based on common characteristics.
- 4 *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.
- 5 *Compare* requires candidates to provide both the similarities and differences between things or concepts.
- 6 *Deduce* is used in a similar way as *predict* except that some supporting statement is required, e.g. reference to a law/principle, or the necessary reasoning is to be included in the answer.
- 7 *Define* (the term(s) ...) is intended literally. Only a formal statement or equivalent paraphrase is required.
- 8 *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the 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*.

- 9 *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.
 - 10 *Discuss* requires candidates to give a critical account of the points involved in the topic.
 - 11 *Draw* is often used in the context of drawing biological specimens. This is an instruction to make a freehand diagram to show the structures observed, as accurately as possible with respect to shape and proportion. Lines delimiting distinct regions should be continuous.
- In other contexts, this will require an accurate representation of the required subject according to the applicable conventions and criteria, e.g. draw the structure of a molecule of glucose
- 12 *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.
 - 13 *Evaluate* is a context-specific term requiring a critical use of information to make a judgement or determination of a particular value or quality (e.g. accuracy). Evaluation of the validity of an experimental procedure, a set of results or a conclusion involves an assessment of the extent to which the procedures, results or conclusions are likely to obtain or represent a ‘true’ outcome. This will require consideration of the advantages and disadvantages, strengths and weaknesses, and limitations of the underlying approach, as well as other relevant criteria as applicable, and their relative importance.
 - 14 *Explain* may imply reasoning or some reference to theory, depending on the context.

- 15 *Find* is a general term that may variously be interpreted as calculate, measure, determine, etc.
- 16 *Justify* requires candidates to give reasoning in support of an answer (for example, a decision, conclusion, explanation or claim), based on a consideration of available evidence, including experimental data, together with relevant scientific knowledge and understanding.
- 17 *Label* requires candidates to use an appropriate label (and labelling line, where necessary) to accurately show the position of a structure, region or point within a diagram or graph, according to the requirements of the assessment.
- 18 *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.
- 19 *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.
- 20 *Outline* implies brevity, i.e. restricting the answer to giving essentials.
- 21 *Predict* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an early part of the question.
- 22 *Recognise* is often used to identify facts, characteristics or concepts that are critical (relevant/appropriate) to the understanding of a situation, event, process or phenomenon.
- 23 *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.

- 24 *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained 'by inspection'.
- 25 *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'.
- 26 *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.