Kingdom of Lesotho
Ministry of Education and Training

LESOTHO GENERAL CERTIFICATE OF SECONDARY EDUCATION

Lesotho General Certificate of Secondary Education

Syllabus

Biology

0180

For examination in November 2018

National Curriculum Development Centre
in collaboration with
Examinations Council of Lesotho

1. Introduction

The two-year Biology syllabus for the Lesotho General Certificate of Secondary Education is designed for all learners of different abilities and educational needs at the Senior Secondary Level, for grades 11 and 12. The Ministry of Education and Training appreciates the need for a syllabus that remains valid for many years to come. It also recognises the importance for its citizens to identify with global educational standards, and to have access to educational institutions within the country, the Southern African Development Community (SADC) region and globally. For this reason, the syllabus has been developed from the basis of the International IGCSE Biology 0610 syllabus of the Cambridge International Examinations (CIE). However this development has produced a syllabus that is distinctly appropriate to the educational needs of the schools of Lesotho.

It achieves progressive learning by building on the foundations laid by Lesotho Junior Certificate Science, and much of the content of that syllabus has been assumed in the construction of this syllabus. However in some topics, it has been thought necessary for clarity to repeat some, but not all, of the Junior Certificate Science content in this syllabus. A good knowledge and understanding of all of Junior Certificate Science is considered necessary for learners proceeding successfully to Lesotho GCSE in Biology.

The syllabus lays a foundation for the CIE AS-level as a Pre-Tertiary qualification.

This syllabus will be examined for the first time in November 2015. Thereafter any minor changes will be published as annexes to this syllabus from time to time. Schools are advised to request such annexes from ECoL when teaching this syllabus for the first time for years after November 2015.

Availability

This syllabus is examined in October/November examination session.

This syllabus is available to all candidates, including private candidates.

2. Syllabus aims and assessment objectives

2.1 Aims

The aims, which are not listed in order of priority, are:

1. to provide a worthwhile educational experience for all candidates, through well-designed studies of experimental and practical science, whether or not they go on to study science beyond this level

2. to enable candidates to acquire sufficient understanding and knowledge to:
   - become confident citizens in a technological world, to take or develop an informed interest in scientific matters
   - recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life
   - be suitably prepared for studies beyond the LGCSE level in pure sciences or in science-dependent vocational courses

3. to develop abilities and skills that:
   - are relevant to the study and practice of biology
   - are useful in everyday life
   - encourage efficient and safe practice
   - encourage effective communication

4. to develop attitudes relevant to biology such as:
   - concern for accuracy and precision
   - objectivity
   - integrity
   - enquiry
   - initiative
   - inventiveness

5. to stimulate interest in, and care for, the environment

6. to promote an awareness that:
   - scientific theories and methods have developed, and continue to do so, as a result of the co-operative activities of groups and individuals
   - the study and practice of science is subject to social, economic, technological, ethical and cultural influence and limitations
   - the applications of science may be both beneficial and detrimental to the individual, the community and the environment
   - science transcends national boundaries and that the language of science, correctly and rigorously applied, is universal

2.2 Assessment objectives

The three assessment objectives in LGCSE Biology are

A Knowledge with understanding
B Handling information and problem solving
C Experimental skills and investigations

A: Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of:

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 material that candidates may be required to recall and explain. Candidates will also be asked questions which require them to apply this materials to unfamiliar contexts and to apply knowledge from one area of the syllabus to knowledge of a different syllabus area.

Questions testing this will often begin with one of the following words: *define, state, describe, explain or outline.*

B: Handling information and problem solving

Candidates should be able, using oral, written, symbolic, graphical and numerical forms of presentation, to:

1. locate, select, organise and present information from a variety of sources,
2. translate information from one form to another,
3. manipulate numerical and other data,
4. use information to identify patterns, report trends and draw inferences,
5. present reasoned explanations for phenomena, patterns and relationships,
6. make predictions and hypotheses,
7. solve problems, including some of a quantitative nature.

Questions testing these skills may be based on information that is unfamiliar to candidates, requiring them to apply the principles and concepts from the syllabus to a new situation, in a logical, reasoned or deductive way.

Questions testing these objectives will often begin with one of the following words: *discuss, predict, suggest, calculate, or determine (see glossary of terms).*

C: Experimental skills and investigations

Candidates should be able to:

1. plan simple investigations and use techniques, apparatus and materials (including the following of a sequence of instructions where appropriate),
2. make and record observations, measurements and estimates,
3. interpret and evaluate experimental observations and data,
4. plan investigations and/or evaluate methods and suggest possible improvements (including the selection of techniques, apparatus and materials).

2.3 Scheme of Assessment

Specification grid

The approximate weightings allocated to each of the assessment objectives in the assessment model are summarised in the table below.

Assessment Objective	Weighting	Paper 1 (marks)	Paper 2 (marks)	Paper 3 (marks)	Total Qualification (%)
A Knowledge with understanding	50%	25-30	48-52	0	47-54
B Handling information and problem solving	30%	10-15	27-32	0	26-33
C Experimental skills and Investigations	20%	0	0	40	20

For the LGCSE in Biology, candidates take three components.

Paper 1 : Multiple Choice	**1 hour**
40 compulsory multiple-choice questions. This paper carries 40 marks. Weighted at 30% of the total qualification.	
Paper 2 : Theory	**1 hour 45 minutes**
This paper has two sections. Section A carries 50 marks and consists of a small number of compulsory, structured questions. Section B carries 30 marks and consists of three compulsory questions. Weighted at 50% of the total qualification.	
Paper 3 : Alternative to practical	**1 hour**
A written paper designed to test familiarity with laboratory-based procedures and past experience of practical work. This paper carries 40 marks. Weighted at 20% of the total qualification.	

2.4 Experimental work

Experimental work is an essential component of all science. Experimental work within science education;

- gives candidates first-hand experience of phenomena
- enables candidates to acquire practical skills
- provides candidates with the opportunity to plan and carry out investigations into practical problems.

This can be achieved by individual or group experimental work, or by demonstrations which actively involve the candidates.

Throughout the Curriculum Content section of this syllabus some clear indications are given of opportunities to use practical work, using the command words '*perform experiments to…'* and '*investigate…'*. These instructions mean that such statements may be examined in terms of practical skills (Skill C) in Paper 3, but also in terms of other skills (Skills A and B) in Papers 1 and 2 covering such skills as planning, prediction, recall, explanation, handling of data (including calculations) and interpretation of results.

2.5 Duration of course

The syllabus is designed to be covered in two years, and should be allocated 6 x 40 minutes lessons each week.

3. Curriculum content

1. Classification and diversity of living organisms

Learning outcomes

Candidates should be able to:

(a) list and describe the characteristics of living organisms;

(b) define and describe the binomial system of naming species as a system in which the scientific name of an organism is made up of two parts showing the genus and species;

(c) identify the main features of the following vertebrates: bony fish, amphibians, reptiles, birds and mammals;

(d) identify the main features used in the classification of the following groups: annelids, nematodes, molluscs, viruses, bacteria and fungi;

(e) use simple dichotomous keys based on easily identifiable features of organisms.

2. Cell structure and organisation

Learning outcomes

Candidates should be able to:

(a) examine under the microscope an animal cell (e.g. liver or cheek epidermal cell) and a plant cell (e.g. from Elodea, a moss, onion epidermis), using an appropriate temporary staining technique, such as iodine or methylene blue;

(b) draw diagrams to represent observations of the plant and animal cells examined above;

(c) identify, from fresh preparations or on diagrams or photomicrographs, the cell membrane, nucleus and cytoplasm in an animal cell;

(d) identify, from diagrams or photomicrographs, the cellulose cell wall, cell membrane, sap vacuole, cytoplasm, nucleus and chloroplasts in a plant cell;

(e) compare the visible differences in structure of the animal and the plant cells examined;

(f) state, in simple terms, the relationship between cell function and cell structure for the following:

- ciliated cells – in respiratory tract;
- root hair cells – absorption;
- xylem vessels – conduction and support;
- muscle cells – contraction;
- red blood cells – transport;

(g) define:
- *tissue* as a group of cells with similar structures, working together to perform a shared function;
- *organ* as a structure made up of a group of tissues, working together to perform specific functions;
- *organ system* as a group of organs with related functions, working together to perform body functions;

(h) calculate magnification and size of biological specimens using millimetres as units.

3. Movement in and out of cells

Learning outcomes

Candidates should be able to:

(a) define *diffusion* as the net movement of molecules from a region of their higher concentration to a region of their lower concentration down a concentration gradient, as a result of their random movement;

(b) state examples of diffusion in living organisms;

(c) define *osmosis* as the diffusion of water molecules from a region of their higher concentration (higher water potential) to a region of their lower concentration (lower water potential), through a partially permeable membrane;

(d) describe and explain the importance of water potential gradient in the uptake of water by plants;

(e) investigate the effect of osmosis in plant and animals tissue;

(f) define *active transport* as movement of ions in or out of a cell through the cell membrane, from a region of their lower concentration to a region of their higher concentration against a concentration gradient, using energy released during respiration;

(g) discuss the importance of active transport as an energy-consuming process by which substances are transported against a concentration gradient, e.g. ion uptake by root hairs and uptake of glucose by epithelial cells of villi.

4. Enzymes

Learning outcomes

Candidates should be able to:

(a) define the term catalyst as a substance that speeds up a chemical reaction and is not changed by the reaction;

(b) define enzymes as proteins that function as biological catalysts;

(c) investigate and describe the effect of changes in temperature and pH on enzyme activity;

(d) explain enzyme action in terms of the 'lock and key' hypothesis;

(e) explain the effect of changes in temperature and pH on enzyme activity;

(f) describe the role of enzymes in the germination of seeds, and their uses in biological washing products and in the food industry (including pectinase and fruit juice);

(g) outline the use of microorganisms and fermenters to manufacture the antibiotic penicillin and enzymes for use in biological washing powders;

(h) describe the role of the fungus *Penicillium* in the production of antibiotic penicillin.

5. Animal nutrition

Learning outcomes

Candidates should be able to:

(a) Define *nutrition* as taking in of nutrients which are organic substances and mineral ions, containing raw materials or energy for growth and tissue repair, absorbing and assimilating them;

(b) list the chemical elements that make up:
- carbohydrates;
- fats;
- proteins;

(c) describe tests for:
- starch (iodine solution);
- reducing sugars (Benedict's solution);
- protein (biuret test);
- fats (ethanol emulsion test);

(d) list the principal sources of, and describe the dietary importance of carbohydrates, fats, proteins, vitamins (C and D only), mineral salts (calcium and iron only), fibre (roughage) and water;

(e) name the diseases and describe the symptoms resulting from deficiencies of vitamin C (scurvy), vitamin D (rickets), mineral salts calcium (rickets) and iron (anaemia);

(f) describe the use of microorganisms in the food industry, with reference to yoghurt and single cell protein;

(g) describe the uses, benefits and health hazards associated with food additives, including colourings;

(h) state what is meant by the term balanced diet and describe a balanced diet related to age, sex and activity of an individual;

(i) describe the effects of malnutrition in relation to starvation, coronary heart disease, constipation and obesity;

(j) define *ingestion* as taking substances (e.g. food, drink) into the body through the mouth;

(k) define *egestion* as passing out of food that has not been digested, as faeces, through the anus;

(l) identify the main regions of the alimentary canal and associated organs including mouth, salivary glands, oesophagus, stomach, small intestine (duodenum and ileum), pancreas, liver, gall bladder, large intestine: colon and rectum, anus;

(m) describe the functions of the regions of the alimentary canal listed above, in relation to ingestion, digestion, absorption, assimilation and egestion of food;

(n) define *digestion* as the break-down of large, insoluble food molecules into small, water-soluble molecules using mechanical and chemical processes;

(o) identify the types of human teeth and describe their structure and functions;

(p) state the causes of dental decay and describe the proper care of teeth;

(q) describe the process of chewing;

(r) describe how fluoride reduces tooth decay and explain arguments for and against the use of fluoride for this purpose;

(s) describe the role of longitudinal and circular muscles in peristalsis;

(t) outline the role of bile in emulsifying fats, to increase the surface area for the action of enzymes;

(u) state the significance of chemical digestion in the alimentary canal in producing small, soluble molecules that can be absorbed;

(v) state where, in the alimentary canal, amylase, protease and lipase enzymes are secreted;

(w) state the functions of a typical amylase, a protease and a lipase, listing the substrate and end-products;

(x) define *absorption* as movement of digested food molecules through the wall of the intestine into the blood or lymph;

(y) identify the small intestine as the region for absorption of digested food;

(z) describe the structure of a villus, including the role of capillaries and lacteals;

(aa) describe the significance of villi in increasing the internal surface area of the small intestine;

(bb) identify the role of the small intestine and the colon in absorption of water (the small intestine absorbs 5–10 dm^3 per day, the colon 0.3–0.5 dm^3 per day);

(cc) state the role of the hepatic portal vein in the transport of absorbed food to the liver;

(dd) define *assimilation* as movement of digested food molecules into the cells of the body where they are used, becoming part of the cells;

(ee) describe the role of the liver in the metabolism of glucose (glucose into glycogen) and amino acids (amino acids into proteins and the destruction of excess amino acids);

(ff) define *deamination* as removal of nitrogen-containing part of amino acids to form urea, followed by release of energy from the remainder of the amino acid;

(gg) describe the role of fat as an energy storage substance.

6. Plant nutrition

Learning outcomes

Candidates should be able to:

(a) define *photosynthesis* as the fundamental process by which plants manufacture carbohydrates from raw materials using energy from light;

(b) state the word and balanced symbol equation for photosynthesis;

(c) investigate the necessity for chlorophyll, light and carbon dioxide for photosynthesis, using appropriate controls;

(d) describe the intake of carbon dioxide and water by plants;

(e) state that chlorophyll traps light energy and converts it into chemical energy for the formation of carbohydrates and their subsequent storage;

(f) investigate and state the effect of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis (e.g. in submerged aquatic plants);

(g) define the term *limiting factor* as something present in the environment in such short supply that it restricts life processes;

(h) explain the concept of limiting factors in photosynthesis;

(i) explain the use of carbon dioxide enrichment, optimum light and optimum temperatures in glasshouse systems;

(j) identify and label the cuticle, cellular and tissue structure of a dicotyledonous leaf, as seen in cross-section under the light microscope, and describe the significance of these features in terms of functions, to include:
- distribution of chloroplasts – photosynthesis;
- stomata and mesophyll cells – gas exchange;
- vascular bundles (xylem and phloem) – transport and support;

(k) describe the importance of:
- nitrate ions in protein synthesis;
- magnesium ions for chlorophyll synthesis;

(l) explain the effects of nitrate ion and magnesium ion deficiency on plant growth.

7. Transport in plants

Learning outcomes

Candidates should be able to:

(a) state the functions of xylem and phloem;

(b) identify the positions of xylem and phloem tissues as seen in transverse sections of unthickened, herbaceous, dicotyledonous roots, stems and leaves;

(c) state the pathway taken by water through the root, stem and leaf (root hair, root cortex cells, xylem, mesophyll cells)

(d) investigate, using a suitable stain, the pathway of water through the above-ground parts of a plant;

(e) define *transpiration* as evaporation of water at the surfaces of the mesophyll cells followed by loss of water vapour from plant leaves, through the stomata;

(f) explain the movement of water through that stem in terms of transpiration pull and capillarity;

(g) describe how water vapour loss is related to cell surfaces, air spaces and stomata;

(h) describe the effects of variation of temperature, humidity and light intensity on transpiration rate;

(i) describe how wilting occurs;

(j) discuss the adaptations of the leaves, stem and roots of plants growing in different contrasting environments, using local examples where possible.

(k) define *translocation* in terms of the movement of sucrose and amino acids in phloem from regions of production to regions of storage or to regions of utilisation in respiration or growth;

(l) describe translocation throughout the plant of applied chemicals, including systemic pesticides;

(m) compare the role of transpiration and translocation in the transport of materials from sources to sinks, within plants at different seasons.

8. Transport in humans

Learning outcomes

Candidates should be able to:

(a) describe the circulatory system as a system of tubes with a pump and valves to ensure one-way flow of blood;

(b) describe the double circulation in terms of a low pressure circulation to the lungs and a high pressure circulation to the body tissues and relate these differences to the different functions of the two circuits;

(c) describe the structure of the heart including the muscular wall and septum, chambers, valves and associated blood vessels;

(d) describe the function of the heart in terms of muscular contraction and the working of the valves;

(e) investigate, state and explain the effect of physical activity on pulse rate;

(f) describe coronary heart disease in terms of the blockage of coronary arteries and state the possible causes (diet, stress and smoking) and preventive measures;

(g) name the main blood vessels to and from the heart, lungs, liver and kidney;

(h) describe the structure and functions of arteries, veins and capillaries;

(i) explain how structure and function are related in arteries, veins and capillaries;

(j) describe the transfer of materials between capillaries and tissue fluid;

(k) identify red and white blood cells as seen under the light microscope on prepared slides, and in diagrams and photomicrographs;

(l) list the components of blood as red blood cells, white blood cells, platelets and plasma;

(m) state the functions of blood:
- red blood cells – haemoglobin and oxygen transport;
- white blood cells – phagocytosis and antibody formation;
- platelets – causing clotting;
- plasma – transport of blood cells, ions, soluble nutrients, hormones, carbon dioxide, urea and plasma proteins;

(n) describe the role of the immune system in tissue rejection;

(o) describe the function of the lymphatic system in circulation of body fluids, and the production of lymphocytes;

(p) describe the process of clotting (fibrinogen to fibrin only).

9. Breathing, gas exchange and respiration

Learning outcomes

Candidates should be able to:

(a) identify on diagrams and name the larynx, trachea, bronchi, bronchioles, alveoli and associated capillaries;

(b) describe the role of the ribs, the internal and external intercostal muscles and the diaphragm in producing volume and pressure changes leading to the ventilation of the lungs;

(c) state the differences in composition between inspired and expired air;

(d) use lime water as a test for carbon dioxide to investigate the differences in composition between inspired and expired air;

(e) list the features of gas exchange surfaces in mammals;

(f) explain the role of mucus and cilia in protecting the gas exchange system from pathogens and particles;

(g) investigate and describe the effects of physical activity on rate and depth of breathing;

(h) explain the link between physical activity and rate and depth of breathing in terms of changes in the rate at which tissues respire and therefore of carbon dioxide concentration and pH in tissues and in the blood;

(i) define *respiration* as the chemical reactions that break down nutrient molecules in living cells to release energy;

(j) state the uses of energy in the body of humans: muscle contraction, protein synthesis, cell division, active transport, growth, the passage of nerve impulses and the maintenance of a constant body temperature;

(k) define *aerobic respiration* as the release of a relatively large amount of energy in cells by the breakdown of food substances in the presence of oxygen;

(l) state the word and balanced equation for aerobic respiration;

(m) define *anaerobic respiration* as the release of a relatively small amount of energy by the breakdown of food substances in the absence of oxygen;

(n) describe the process of anaerobic respiration in muscles and microorganisms;

(o) state the word equation for anaerobic respiration in muscles during hard exercise and in the microorganism yeast;

(p) describe the effect of lactic acid in muscles during exercise (include oxygen debt in outline only);

(q) describe the role of anaerobic respiration in yeast during brewing and bread-making;

(r) compare aerobic respiration and anaerobic respiration in terms of relative amounts of energy released, oxygen use and products.

10. Excretion in humans

Learning outcomes

Candidates should be able to:

(a) define *excretion* as the removal from organisms of toxic materials, the waste products of metabolism (chemical reactions in cells including respiration) and substances in excess of requirements. Substances should include carbon dioxide by the lungs and urea and salts by the kidneys;

(b) describe the function of the kidney in terms of the removal of urea and excess water and the reabsorption of glucose and some salts;

(c) state the relative positions of ureters, bladder and urethra in the body;

(d) state that urea is formed in the liver from excess amino acids;

(e) state that alcohol, drugs and hormones are broken down in the liver;

(f) outline the structure of a kidney to include the cortex, medulla, and the start of the ureter (details of kidney and nephron structure are **not** required);

(g) outline the structure and functioning of a kidney tubule including:
- role of renal capsule in filtration from blood of water, glucose, urea and salts;
- role of tubule in reabsorption of glucose, most of the water and some salts back into the blood, leading to concentration of urea in the urine as well as loss of excess water and salts;

(h) explain dialysis in terms of maintenance of glucose and protein concentration in blood and diffusion of urea from blood to dialysis fluid;

(i) discuss the application of dialysis in kidney machines;

(j) discuss the advantages and disadvantages of kidney transplants, compared with dialysis.

11. Coordination and response

Learning outcomes

Candidates should be able to:

(a) describe the human nervous system in terms of the central nervous system (brain and spinal cord as areas of coordination) and the peripheral nervous system which together serve to coordinate and regulate body functions;

(b) identify, on diagrams of the nervous system, the cerebellum, pituitary gland, hypothalamus, medulla, spinal cord and nerves;

(c) describe the principal functions of the above structures in terms of coordinating and regulating bodily functions;

(d) identify motor (effector), relay (connector) and sensory neurones from diagrams;

(e) describe a reflex action as a means of automatically and rapidly integrating and coordinating stimuli with responses;

(f) describe a simple reflex arc in terms of sensory, relay and motor neurons;

(g) state that muscles and glands can act as effectors;

(h) describe the action of antagonistic muscles to include the biceps and triceps at the elbow joint;

(i) define sense organs as groups of receptor cells responding to specific stimuli: light, sound, touch, temperature and chemicals;

(j) describe the structure and function of the eye, including accommodation and pupil reflex;

(k) distinguish between voluntary and involuntary actions;

(l) define a *hormone* as a chemical substance, produced by a gland, carried by the blood, which alters the activity of one or more specific target organs and is then destroyed by the liver;

(m) state the role of the hormone adrenaline in chemical control of metabolic activity, including increasing the blood glucose concentration and pulse rate;

(n) give examples of situations in which adrenaline secretion increases;

(o) compare nervous and hormonal control systems;

(p) define and investigate *geotropism* (as a response in which a plant grows towards or away from gravity) and *phototropism* (as a response in which a plant grows towards or away from the direction from which light is coming);

(q) explain the chemical control of plant growth by auxins including geotropism and phototropism in terms of auxins regulating differential growth, and the effects of synthetic plant hormones used as weedkillers.

12. Homeostasis

Learning outcomes

Candidates should be able to:

(a) define *homeostasis* as the maintenance of a constant internal environment;

(b) identify, on a diagram of the skin: hairs, sweat lands, temperature receptors, blood vessels and fatty tissue;

(c) describe the maintenance of a constant body temperature in humans in terms of insulation and the role of temperature receptors in the skin, sweating, shivering, vasodilation and vasoconstriction of arterioles supplying skin-surface capillaries and the coordinating role of the brain;

(d) explain the concept of control by negative feedback;

(e) describe the control of glucose content of the blood by the liver, and by insulin and glucagon from the pancreas;

(f) describe the causes, signs, symptoms and control of diabetes mellitus;

(g) describe the role of the pituitary gland and the hormone ADH in osmoregulation.

13. The use and abuse of drugs

Learning outcomes

Candidates should be able to:

(a) define a *drug* as any substance that when taken into the body modifies or affects chemical reactions in the body;

(b) describe the medicinal use of antibiotics for the treatment of bacterial infection;

(c) describe the importance of the correct use of antibiotics to prevent bacterial resistance

(d) explain why antibiotics kill bacteria but not viruses;

(e) describe the effects of dagga and cocaine as drugs of abuse;

(f) describe the effects of excessive consumption of alcohol: reduced self-control, depressant, effect on reaction times, damage to liver and social implications;

(g) describe the effects of tobacco smoke and its major toxic components (tar, nicotine, carbon monoxide, smoke particles) on the gas exchange system;

(h) describe the effects of the abuse of heroin. Problems of addiction, severe withdrawal symptoms and associated problems such as crime and infection e.g. HIV/AIDS.

14. Nuclear division

Learning outcomes

Candidates should be able to:

(a) define the terms:
- *chromosome* as a thread of DNA, made up of a string of genes;
- *gene* as a length of DNA that is the unit of heredity and codes for a specific protein;
- *allele* as any of two or more alternative forms of a gene;
- *homologous* chromosomes as similar chromosomes containing similar genes;
- *haploid* nucleus as a nucleus containing a single set of unpaired chromosomes (e.g. sperm and egg);
- *diploid* nucleus as a nucleus containing two sets of chromosomes (e.g. in body cells);

(b) define *mitosis* as nuclear division giving rise to genetically identical cells in which the chromosome number is maintained by the exact duplication of chromosomes (details of stages are **not** required);

(c) state the role of mitosis in growth, repair of damaged tissues, replacement of worn out cells and asexual reproduction;

(d) define *meiosis* as reduction division in which the chromosome number is halved from diploid to haploid (details of stages are **not** required);

(e) state that gametes are the result of meiosis;

(f) state that meiosis results in genetic variation so the cells produced are not all genetically identical.

15. Reproduction in plants and animals

Learning outcomes

Candidates should be able to:

(a) define *sexual reproduction* as the process involving the fusion of haploid nuclei to form a diploid zygote and the production of genetically dissimilar offspring;

(b) discuss the advantages and disadvantages to a species of sexual reproduction;

(c) define *asexual reproduction* as the process resulting in the production of genetically identical offspring from one parent;

(d) describe asexual reproduction in bacteria, spore production in fungi and tuber formation in potatoes;

(e) discuss the advantages and disadvantages to a species of asexual reproduction;

(f) describe the importance of the commercial applications of asexual reproduction;

(g) identify and describe the sepals, petals, stamens, anthers, carpels, ovaries and stigmas of one, locally available, named, insect-pollinated, dicotyledonous flower (candidates should expect to apply their understanding of the flowers they have studied to unfamiliar flowers);

(h) state the functions of the sepals, petals, anthers, stigmas and ovaries;

(i) identify and describe the anthers and stigmas of one, locally available, named, wind-pollinated flower (candidates should expect to apply their understanding of the flowers they have studied to unfamiliar flowers);

(j) examine under a microscope or in photomicrographs and explain differences in the structure of pollen grains from wind-pollinated and insect-pollinated flowers;

(k) define *pollination* as the transfer of pollen grains from the male part of the plant (anther of cross-pollination stamen) to the female part of the plant (stigma);

(l) distinguish between self-pollination and cross-pollination;

(m) discuss the implications to a species of self-pollination and cross-pollination;

(n) name wind and insects as agents of pollination;

(o) compare the different structural adaptations of insect-pollinated and wind-pollinated flowers;

(p) describe the growth of the pollen tube and its entry into the ovule followed by fertilisation (production of endosperm and details of development are **not** required);

(q) investigate and describe the structure of a non-endospermic seed in terms of the embryo (radicle, plumule and cotyledons) and testa, protected by the fruit;

(r) outline the formation of a seed (limited to embryo, cotyledons, testa and role of mitosis) and fruit (produced from the ovary wall);

(s) state that seed and fruit dispersal by wind and by animals provides a means of colonising new areas;

(t) describe, using named examples, seed and fruit dispersal by wind and by animals;

(u) explain differences in male and female gametes in terms of size, number and motility;

(v) identify on diagrams of the male reproductive system, the testes, scrotum, sperm ducts, prostate gland, urethra and penis, and state the functions of these parts;

(w) identify on diagrams of the female reproductive system, the ovaries, oviducts, uterus, cervix and vagina, and state the functions of these parts;

(x) describe the roles of testosterone and oestrogen and progesterone in the development and regulation of secondary sexual characteristics at puberty;

(y) describe the menstrual cycle in terms of changes in the uterus and ovaries (due to oestrogen and progesterone) with reference to the fertile cycle;

(z) explain the role of hormones in controlling changes in the uterus and ovaries the menstrual cycle (including FSH, LH, progesterone and oestrogen);

(aa) outline fertilisation in terms of the joining of the nuclei of male gamete (sperm) and the female gamete (egg);

(bb) describe the effect of the chemical changes on the surface of the ovum during fertilization;

(cc) outline early development of the zygote simply in terms of the formation of a ball of cells that becomes implanted in the wall of the uterus;

(dd) outline the development of the fetus;

(ee) describe the function of the placenta and amniotic fluid, amniotic sac, umbilical cord in relation to exchange of dissolved nutrients, gases and excretory products (structural details are **not** required);

(ff) describe the ante-natal care of pregnant women including special dietary needs and maintaining good health;

(gg) outline the processes involved in labour and birth;

(hh) describe the advantages and disadvantages of breast-feeding compared with bottle-feeding using formula milk;

(ii) outline the following methods of birth control: natural (abstinence, rhythm method) chemical (contraceptive pill, spermicide) mechanical (condom, diaphragm, femidom, IUD) surgical (vasectomy, female sterilisation);

(jj) describe the reliability of the rhythm method in terms of the life-spam of the ovum and the sperms as well as the regularity of the menstrual cycle;

(kk) outline artificial insemination and the use of hormones in fertility drugs, and discuss their social implications;

(ll) state the causative agent and describe the symptoms, signs, effects and treatment of syphilis;

(mm) describe the methods of transmission of human immunodeficiency virus (HIV), and the ways in which HIV/AIDS can be prevented from spreading;

(nn) outline how HIV affects the immune system in a person with HIV/AIDS.

16. Growth and development

Learning outcomes

Candidates should be able to:

(a) define *growth* in terms of a permanent increase in size and dry mass by an increase in cell number or cell size or both;

(b) define *development* in terms of increase in complexity;

(c) investigate and state the environmental conditions that affect germination of seeds: requirement for water and oxygen, suitable temperature.

17. Inheritance

Learning outcomes

Candidates should be able to:

(a) define *inheritance* as the transmission of genetic information from generation to generation;

(b) describe the inheritance of sex in humans (XX and XY chromosomes);

(c) define the terms:
- *genotype* as genetic makeup of an organism in terms of the alleles present (e.g. Tt or GG);
- *phenotype* as the physical or other features of an organism due to both its genotype and its environment (e.g. tall plant or green seed);
- *homozygous* as having two identical alleles of a particular gene (e.g. TT or gg). Two identical *homozygous* individuals that breed together will be pure-breeding;
- *heterozygous* as having two different alleles of a particular gene (e.g. Tt or Gg), not pure-breeding;
- *dominant* as an allele that is expressed if it is present (e.g. T or G);
- *recessive* as an allele that is only expressed when there is no dominant allele of the gene present (e.g. t or g);

(d) calculate and predict the results of monohybrid crosses involving 1 : 1 and 3 : 1 ratios;

(e) explain codominance by reference to the inheritance of ABO blood groups (phenotypes, A, B, AB and O blood groups and genotypes I^A, I^B, and I^O);

(f) state that continuous variation is influenced by genes and environment, resulting in a range of phenotypes between two extremes, e.g. height, skin colour in humans;

(g) state that discontinuous variation is caused by genes alone and results in a limited number of distinct phenotypes with no intermediates e.g. A, B, AB and O blood groups in humans, sex determination;

(h) define *mutation* as a change in a gene or chromosome;

(i) describe mutation as a source of variation, as shown by Down's syndrome;

(j) outline the effects and consequences of ionising radiation and chemicals on the rate of mutation;

(k) describe sickle cell anaemia and explain its incidence in relation to that of malaria;

(l) describe the role of artificial selection in the production of varieties of animals and plants with increased economic importance;

(m) define *natural selection* as the greater chance of passing on of genes by the best adapted organisms;

(n) describe variation and state that competition leads to differential survival of, and reproduction by, those organisms best fitted to the environment

(o) explain the importance of natural selection as a possible mechanism for evolution;

(p) describe the development of strains of antibiotic resistant bacteria as an example of natural selection;

(q) define *genetic engineering* as altering the genetic makeup of an organism by introducing or removing genetic material;

(r) explain that the gene that controls the production of human insulin can be inserted into bacterial DNA;

(s) understand that such genetically engineered bacteria can be used to produce human insulin on a commercial scale;

(t) discuss potential advantages and dangers of genetic engineering.

18. Relationships of organisms with one another and with the environment

Learning outcomes

Candidates should be able to:

(a) state that the Sun is the principal source of energy input to biological systems;

(b) describe the non-cyclical nature of energy flow;

(c) define the terms:

- *food chain* as a chart showing the flow of energy (food) from one organism to the next beginning with a producer (e.g. mahogany tree →Caterpillar →song bird → hawk);
- *food web* as a network of interconnected food chains showing the energy flow through part of an ecosystem;
- *producer* as an organism that makes its own organic nutrients, usually using energy from sunlight, through photosynthesis;
- *consumer* as an organism that gets its energy by feeding on other organisms;
- *herbivore* as an animal that gets its energy by eating plants;
- *carnivore* as an animal that gets its energy by eating other animals;
- *decomposer* as an organism that gets its energy from dead or waste organic matter;
- *ecosystem* as a unit containing all of the organisms and their environment, interacting together, in a given area e.g. decomposing log or a lake;
- *trophic level* as the position of an organism in a food chain, food web or pyramid of biomass, numbers or energy;

(d) describe energy losses between trophic levels;

(e) draw, describe and interpret pyramids biomass and numbers;

(f) explain why food chains usually have fewer than five trophic levels;

(g) explain why there is an increased efficiency in supplying green plants as human food and that there is a relative inefficiency, in terms of energy loss, in feeding crop plants to animals;

(h) describe and state the importance of the carbon cycle;

(i) describe the nitrogen cycle in terms of:
- the role of microorganisms in providing usable nitrogen-containing substances by decomposition and by nitrogen fixation in roots;
- the absorption of these substances by plants and their conversion to protein followed by passage through food chains, death, decay nitrification and denitrification and the return of nitrogen to the soil or the atmosphere (names of individual bacteria are **not** required);

(j) discuss the effects of the combustion of fossil fuels and the cutting down of forests on the oxygen and carbon dioxide concentrations in the ecosystem;

(k) define *population* as a group of organisms of one species, living in the same area at the same time;

(l) state the factors affecting the rate of population growth for a population of an organism (limited to food supply, predation and disease), and describe their importance;

(m) identify the lag, potential (log), stationary death phases in the sigmoid population growing in an environment with limited resources;

(n) describe the change in human population size and its implications;

(o) explain the factors that lead to the lag phase, exponential (log) phase and stationary phase in the sigmoid curve population growth reference, making reference, where appropriate, to the limiting factors;

(p) interpret graphs and diagrams of human population growth;

(q) outline the effects of humans on ecosystems, with emphasis on examples of international importance (tropical rain forests, oceans and important rivers);

(r) list the undesirable effects of deforestation (to include extinction, loss of soil, flooding, carbon dioxide build up);

(s) describe the undesirable effects of overuse of fertilisers (to include eutrophication of lakes and rivers);

(t) discuss the use of locally available organic mature over chemical fertilisers;

(u) describe the undesirable effects of pollution to include:
- the effects of non-biodegradable plastics in the environment;
- water pollution by sewage and chemical waste;
- the causes and effects on the environment of acid rain, and the measures that might be taken to reduce its incidence;
- how increases in greenhouse gases (carbon dioxide and methane) are thought to cause global warming;
- pollution due to pesticides including insecticides and herbicides;
- pollution due to nuclear fall-out;

(v) identify pollution in the local environment and discuss ways in which it can be prevented;

(w) discuss the use of hormones in agricultural food production (names **not** required); describe the need for conservation of natural resources (limited to water and non-renewable materials including fossil fuels);

(x) explain how limited and non-renewable resources can be recycled (including recycling of paper and treatment of sewage to make the water safe to return to the environment or for human use).

4. Alternative to practical

This paper is designed to test candidates' familiarity with laboratory practical procedures.

Questions may be set requiring the candidates to:

- follow carefully a sequence of instructions
- use familiar, and unfamiliar, techniques to record observations and make deductions from them
- recall simple physiological experiments, e.g. tests for food substances, the use of a photometer
- and the use of hydrogen carbonate indicator, litmus and Universal Indicator paper
- recognise, observe and record familiar, and unfamiliar, biological specimens
- make a clear line drawing from a photograph (or other visual representation) of a specimen, indicate the magnification of the drawing and label, as required
- perform simple arithmetical calculations
- record readings from apparatus
- describe, explain or comment on experimental arrangements and techniques
- complete tables of data
- draw conclusions from observations and/or from information given
- interpret and evaluate observations and experimental data
- plot graphs and/or interpret graphical information
- identify sources of error and suggest possible improvements in procedures
- plan an investigation, including suggesting suitable techniques and apparatus.

5. Appendix

5.1 Laboratory equipment

The following is a list of the conditions, materials and equipment that are considered appropriate for the teaching of LGCSE Biology.

A hazard appraisal of the list has been carried out. The following codes are used where relevant:

C = corrosive substance
H = harmful or irritating substance
T = toxic substance
F = highly flammable substance
O = oxidising substance
N = harmful to the environment

Laboratory conditions

- Adequate bench space (more than 1m × 1m for each candidate)
- Water supply – not necessarily mains supply
- Gas supply (for heating) – mains/cylinder
- Electrical supply – mains/batteries/generator
- Secure area for preparation and storage of items made for practical lessons and tests

Apparatus and materials

Safety equipment appropriate to the work being planned, but at least including eye protection such as safety spectacles or goggles

Chemical reagents

- hydrogencarbonate indicator (bicarbonate indicator)
- **[H]** iodine in potassium iodide solution (iodine solution)
- **[H]** Benedict's solution(or an alternative such as Fehling's)
- **[C]** Biuret reagent(s) (sodium or potassium hydroxide solution and copper sulfate solution)
- **[F]** ethanol/methylated spirit
- cobalt chloride paper
- pH indicator paper or universal indicator solution or pH probes
- litmus paper
- glucose
- sodium chloride
- aluminium foil or black paper

Instruments

- rulers capable of measuring to 1 mm
- mounted needles or seekers or long pins with large head
- means of cutting biological materials e.g. scalpels, solid-edged razor blades or knives
- scissors
- forceps
- means of writing on glassware (e.g. wax pencil, water-resistant marker, small self-adhesive labels and pencils)

Glassware and similar (some of which may be glass, plastic or metal)

- beakers or other containers
- test-tubes, test-tube racks and test-tube holders
- funnels
- droppers or teat pipettes or plastic or glass dispensing bottles
- dishes such as Petri dishes or tin lids
- means of measuring small and larger volumes of liquids such as syringes, graduated pipettes or measuring cylinders
- glass rod
- capillary tube

Additional equipment

- thermometers (covering at least the range 0–100°C; any range starting below 0 and ending above 100°C is suitable)
- means of heating such as Bunsen or other gas burner or spirit burner
- glass slides and coverslips
- white tile or other suitable cutting surface
- visking tube or other partially permeable membrane material
- hand lens (at least X6)

Desirable apparatus and materials

Microscope with mirror and lamp or with built in light, at least low-power (X10) objective, optional high- power (X40) objective will greatly increase the range of cellular detail that can be resolved.

Chemical reagents in addition to those listed above

- **[H]** copper sulfate(blue crystals)
- **[H]** dilute (1 mol dm^{-3}) hydrochloric acid
- a source of distilled or deionised water
- eosin/red ink
- **[H]** limewater
- **[H]** methyleneblue
- **[C]** potassium hydroxide
- sodium hydrogencarbonate (sodium bicarbonate)
- Vaseline/petroleum jelly (or similar)
- Mortar and pestle or blender

4.3 Grade descriptors

The scheme of assessment is intended to encourage positive achievement by all candidates.

Grade A	**Candidate must show mastery of the curriculum.**
A **Grade A** candidate will be able to:	• relate facts to principles and theories and vice versa • state why particular techniques are preferred for a procedure or operation • select and collate information from a number of sources and present it in a clear logical form • solve problems in situations which may involve a wide range of variables • process data from a number of sources to identify any patterns or trends • generate a hypothesis to explain facts, or find facts to support a hypothesis
Grade C	**Candidate must show a high level of competence in the curriculum.**
A **Grade C** candidate will be able to:	• link facts to situations not specified in the syllabus • describe the correct procedure(s) for a multi-stage operation • select a range of information from a given source and present it in a clear logical form • identify patterns or trends in given information • solve a problem involving more than one step, but with a limited range of variables • generate a hypothesis to explain a given set of facts or data
Grade F	**Candidate must show competence in the curriculum.**
A **Grade F** candidate will be able to:	• recall facts contained in the syllabus • indicate the correct procedure for a single operation • select and present a single piece of information from a given source • solve a problem involving one step, or more than one step if structured help is given • identify a pattern or trend where only minor manipulation of data is needed • recognise which of two given hypotheses explains a set of facts or data

4.4 Terminology, units, symbols and presentation of data

4.4.1 Numbers

The decimal point will be placed on the line, e.g. 52.35.

Numbers from 1000 to 9999 will be printed without commas or spaces.

Numbers greater than or equal to 10000 will be printed without commas. A space will be left between each group of three whole numbers, e.g. 4 256 789.

4.4.2 Units

The International System of units will be used (SI units). Units will be indicated in the singular not in the plural, e.g. 28 kg.

The solidus (/) will **not** be used for a quotient, e.g. m/s for metres per second. In practical work, candidates will be expected to use SI units. The use of imperial/customary units, such as the inch and the degree Fahrenheit, should be discouraged.

Quantity	Name of unit	Symbol
length	kilometre	km
	metre	m
	centimetre	cm
	millimetre	mm
	micrometre	μm
mass	tonne (1000 kg)	
	kilogram	kg
	gram	g
	milligram	mg
	microgram	μg
temperature	degrees Celsius	°C
time	year	y
	day	d
	hour	h

	minute	min
	second	s
amount of substance	mole	mol
Derived SI units		
energy	kilojoule	kJ
	joule (calorie is obsolete)	J
Recommended units for area, volume and density		
area	hectare = 10^4 m^2	ha
	square metre	m^2
	square decimetre	dm^2
	square centimetre	cm^2
	square millimetre	mm^2
volume	cubic kilometre	km^3
	cubic metre	m^3
	cubic decimetre (preferred to litre)	dm^3
	litre	dm^3 (**not** *l*)
	cubic centimetre	cm^3 (**not** *ml*)
	cubic millimetre	mm^3
density	kilogram per cubic metre	kg m^{-3}
	gram per cubic centimetre	g cm^{-3}

4.4.3 Presentation of data

The solidus (/) is to be used for separating the quantity and the unit in tables, graphs and charts, e.g. time/s for time in seconds.

(a) *Tables*

Each column of a table will be headed with the physical quantity and the appropriate unit, e.g.time/s. There are three acceptable methods of stating units, e.g. metres per sec or m per s or ms^{-1}.

The column headings of the table can then be directly transferred to the axes of a constructed graph.

(b) *Graphs*

Each axis will be labelled with the physical quantity and the appropriate unit, e.g. time/s.
The graph is the whole diagrammatic presentation. It may have one or several curves plotted on it.

Curves and lines joining points on the graph should be referred to as 'curves'.
Points on the curve should be clearly marked as crosses (x) or encircled dots (⊙). If a further curve is included, vertical crosses (+) may be used to mark the points.

(c) *PieCharts*

These should be drawn with the sectors in rank order, largest first, beginning at 'noon' and proceeding clockwise. Pie Charts should preferably contain no more than six sectors.

(d) *Bar Charts*

These are drawn when one of the variables is not numerical, e.g. percentage of vitamin C in different fruits. They should be made up of narrow blocks of equal width that do **not** touch.

(e) *Histograms*

These are drawn when plotting frequency graphs with continuous data, e.g. frequency of occurrence of leaves of different lengths. The blocks should be drawn in order of increasing or decreasing magnitude and they **should** be touching.

4.4.4 Taxonomy

(a) Taxonomy is the study of the principles of the organisation of taxa into hierarchies. There are seven levels of taxon – kingdom, phylum, class, order, family, genus and species. These may be used when teaching the concept and use of a classificatory system, the variety of organisms, and the binomial system. The following should apply:

(b) Five Kingdoms are now recognized as prokaryotes (Prokaryotae), including bacteria and blue-green bacteria protoctists (Protoctista), including green, red and brown algae and protozoans fungi (Fungi) plants (Plantae) animals (Animalia)

(c) The viruses cannot be fitted into this classificatory system.

(d) The binomial system of naming gives each organism a two-word name, e.g. *Homo sapiens*. The first word is the generic name (genus) and the second word is the specific name (species).

(e) Generic and species names are distinguished from the rest of the text either by being set in italics (in print) or by underlining (when written or typed).

(f) The generic name always takes an initial capital (upper case) letter. It can be accepted as a shorthand for the specific name where the intent is obvious, e.g. *Plasmodium*, and in these circumstances can stand alone. The specific name always has an initial small (lower case) letter when following the generic name, e.g. *Escherichia coli*.

(g) The scientific name should generally be written in full when it is first used, but may then be abbreviated when subsequently used, e.g. *Escherichia coli* becomes *E. coli*.

(h) The common name should not normally be written with an initial capital letter, e.g. cat and dog. The exception is Man, where it is the common name for a species where the two sexes are distinguished by the terms man and woman.

(i) A species is not easy to define but an acceptable general definition is as follows: 'A group of organisms capable of interbreeding and producing fertile offspring'.

4.4.5 Genetics

(a) The terms gene and allele are not synonymous. A gene is a specific length of DNA occupying a position called a locus. A specific function can be assigned to each gene. An allele is one of two or more different forms of a gene.

(b) A standard form of presenting genetic crosses should be adopted. The following symbols should be used as shown: P designates the cross of pure-breeding (homozygous) individuals F1 designates the offspring of homozygous parents F2 designates the offspring produced by crossing F1 parents.

(c) The format for the course of a genetic cross should be labelled as shown: parental phenotypes parental genotypes gametes offspring genotypes offspring phenotypes etc.

(d) The gene should be designated by a letter or letters so that upper and lower case versions are easily distinguishable, e.g. B and b. The upper case letter indicates the dominant allele and the lower case letter indicates the recessive allele.

(e) The symbols for gametes should be circled to indicate the discrete nature of each gamete.

(f) Some form of checkerboard should be used to demonstrate genotypes that can result from random fusion of gametes. Candidates should understand that genotypes are only possible combinations and that only a very large number of offspring can result in all combinations being achieved.

(g) The term incomplete dominance should be discontinued and in the particular case where alleles are equally dominant it should be called codominance. Thus codominance should be used where the influence of both alleles is shown in the phenotype, e.g. the AB blood group in humans.

4.4.6 Terminology

(a) Wherever possible, English terms should be used in preference to Latin or Greek terms, e.g. the term red blood cell should be used and not erythrocyte.

(b) Generalised terms should be stated in English, e.g. small intestine.

(c) Where no suitable English terms exist, Latin terms are unavoidable and will need to be used, e.g. atrium, bronchi, villi.

4.5 Glossary of terms

This glossary (which is relevant only to Science subjects) will prove helpful to candidates as a guide, but 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. (a) *Explain* may imply reasoning or some reference to theory, depending on the context. It is another way of asking candidates to give reasons for. The candidate needs to leave the examiner in no doubt **why** something happens.

   (b) *Give a reason/Give reasons* is another way of asking candidates to explain **why** something happens.

6. (a) *Describe*, the data or information given in a graph, table or diagram, requires the candidate to state the key points that can be seen in the stimulus material. Where possible, reference should be made to numbers drawn from the stimulus material.

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

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

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

9. *Predict* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question. *Predict* also implies a concise answer, with no supporting statement required.

10. *Deduce* is used in a similar way to predict except that some supporting statement is required, e.g. reference to a law or principle, or the necessary reasoning is to be included in the answer.

11. (a) *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer (e.g. in Biology, there are a variety of factors that might limit the rate of photosynthesis in a plant in a glasshouse),

    (b) *Suggest* may also be used to imply that candidates are expected to apply their general knowledge and understanding of biology to a 'novel' situation, one that may be formally 'not in the syllabus' – many data response and problem solving questions are of this type.

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 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.

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.

In all questions, the number of marks allocated are shown on the examination paper, and should be used as a guide by candidates to how much detail to give. In describing a process the mark allocation should guide the candidate about how many steps to include. In explaining why something happens, it guides the candidate how many reasons to give, or how much detail to give for each reason.

4.6 Mathematical requirements

Calculators may be used in all parts of the examination.

Candidates should be able to:

- add, subtract, multiply and divide
- understand averages, decimals, fractions, percentages, ratios and reciprocals
- recognise and use standard notation
- use direct and inverse proportion
- use positive, whole number indices
- draw charts and graphs from given data
- interpret charts and graphs
- select suitable scales and axes for graphs
- make approximate evaluations of numerical expressions
- recognise and use the relationship between length, surface area and volume and their units, on metric scales
- use usual mathematical instruments (ruler, compasses)
- understand the meaning of radius, diameter, square, rectangle.

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