Scottish Certificate of Education

Standard Grade Revised Arrangements in Biology

General and Credit Levels in and after 1999

STANDARD GRADE ARRANGEMENTS IN BIOLOGY

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Introduction

This document sets out the arrangements for examinations in Standard Grade Biology which have been developed in the light of a two-stage consultation exercise carried out between November 1995 and February 1997. The consultation initially sought the views of interested bodies and presenting centres on a range of alternative models for assessment of Practical Abilities in the sciences and latterly on proposed amended arrangements.

Examinations in Biology at General and Credit Levels based on these Arrangements will be offered in and after 1999.

Section 1

Course Rationale

1 Course Rationale

1 1 As a contribution to general education, Biology should provide pupils with an understanding of themselves and the natural world in which they live. The Standard Grade course gives emphasis to the role of practical activity and investigation as vehicles for extending pupils' knowledge of the subject and developing necessary skills. The course provides a basis for further study of the subject, although the intention is not in the first instance to produce professional biologists. Recognition of the demands of society and of the need to produce citizens who are aware of the biological benefits and hazards which will impinge on their everyday lives plays a significant part in the course.

The scope of Biology, the boundaries of which are rapidly extending, is extremely wide and varied, including not only the traditional study of plants and animals and their environments, but also of such areas as molecular biology and biotechnology which have clear relevance to modern society. The problem this poses in selecting course content was recognised by a Joint Working Party comprising members of the Scottish Examination Board's Biology Panel and of the Scottish Central Committee on Science set up to review the SCE Ordinary Grade syllabus. That Joint Working Party acknowledged in its report (published in 1981) the overloading of factual content of that syllabus to the detriment of the desirable development of skills and processes. The report also recorded teachers' dissatisfaction with alleged neglect of "whole plant and animal biology", the lack of "balance with Applied Biology and Natural History" and an approach which was insufficiently pupil-centred. There has been a tendency in the past to approach syllabus construction through a sampling of all that is encompassed by the subject. This approach, combined with the competing claims of specialists from different areas of the subject for inclusion of particular items of content, has in some measure made overloading and imbalance inevitable consequences. As a partial solution to the problem of content, the 1981 report recommended incorporation of optional topics in the future Biology course at Standard Grade.

In the initial consultation during the Standard Grade development programme, regional and national representatives of Biology teachers overwhelmingly rejected optional topics as a possible feature of the Standard Grade course. This view was subsequently re-affirmed in later consultation on preliminary course proposals. The initial consultation also indicated that many teachers were concerned that skills and processes rather than content should be emphasised in the course. Limitation of the recommended time allocation for the course to 160 hours presented additional problems concerning the amount of content to be included.

1 2 With these considerations in mind, the course is based on seven prescribed topics (see 1 2 3).

1 2 1 These topics provide:

- a wide contextual experience of current thinking and practice in biology
- opportunities for pupils to develop a range of abilities which are appropriate to processes involved in biological investigation
- interest and motivation for pupils of a wide range of abilities, including those for whom study of an academic discipline for its own sake has little attraction
- biological content relevant to perceived needs of society now and in the future
- a framework within which pupils' understanding of some important biological ideas or concepts may be progressively developed.

1 2 2 The topics are derived from the following three general aspects.

The biological basis for life:

From this, the study of cells, growth in plants and the processes necessary for survival of animals arise. The study of inheritance and of the mechanisms for continuity and change from generation to generation, is also appropriate.

Relationships:

The study of ecology provides a basis for understanding the interactions amongst organisms and their environments. This is extended to a consideration of man's influence on the dynamic balance of organisms in the natural world.

Application of biological principles in work, health and leisure activities:

The increasing importance of biological products in industry makes biotechnology a natural topic for study. Interest and participation in sport plays a major part in leisure activities for people of all ages. More than ever before, emphasis on healthy living is a feature of our society. Inclusion of a topic on the physiological basis of movement and the effects of exercise on physical fitness and performance is considered appropriate within this context.

1 2 3 The seven topics are as follows:

- The Biosphere
- The World of Plants
- Animal Survival
- Investigating Cells
- The Body in Action
- Inheritance
- Biotechnology.

The above sequence is not a prescribed route through the subject. Biology teachers have always needed considerable flexibility in planning their presentation and the continued application of teachers' professional skills in this direction is to be encouraged.

Examples of the way in which particular ideas and concepts are common to a number of topics in the course are given in the table overleaf.

Ideas and Concepts Common to Topics

TOPICS / IDEAS/CONCEPTS	THE BIOSPHERE	THE WORLD OF PLANTS	ANIMAL SURVIVAL	INVESTIGATING CELLS	THE BODY IN ACTION	INHERITANCE	BIOTECHNOLOGY
The cell as a dynamic centre for growth and manufacture of chemicals				cell division, enzyme, cell respiration, energy use		cells, chromosomes, genes	single-celled organism, products, control by chromosomes
Food as a source of energy, protein, etc	producers and consumers, food chains, protein conversion, nutrient cycles	production by green plants of their own food	food needs of animals, chemical nature of food	energy needs of cells, food as source of energy			sugar as food material for yeast, production of protein-rich food
Energy relations and transformation	energy flow and energy from organic waste used by bacteria	energy conversion in photo-synthesis, chlorophyll and light energy		release of energy in cells, energy available in food materials, energy needs, importance of heat	energy and contraction of muscles, respiration		energy levels, waste, decay and energy, needs of micro-organisms, energy from micro-organisms
Adaptation to change; survival	factors influencing distribution, competition, tolerance to pollution	variety of plants, survival in relation to dispersal of seeds and fruits, effect of environ-mental conditions on plants	needs of animals, internal and external fertilisation, protection of young, water balance and conservation, excretion, life cycles			variation survival, types of variation, inheritance of characteristics, selective breeding	genetic engineering, hazards of new strains of bacteria
Control	factors controlling distribution and population growth, control of energy in waste by micro-organisms		control of internal environment by kidney	control by cell membrane, nucleus	need for control in movement		
Pollution	sources and effects of pollution of air, water; means of reducing effects	effects of plants, and their use, on the environment; pollution from burning fossil fuels					sewage and the environment, sewage treatment, useful products from waste
Enzymes and chemical reaction			enzymes in break-down of food	enzymes in cells, effect on pace of reaction, effects on conditions of enzyme action breakdown and synthesis			enzymes as bacterial products, effect of temperature change on enzyme activity, use of enzymes for controlling reactions

Ideas and Concepts Common to Topics *(continued)*

Health and Safety			food needs of animals, digestion, reproduction, kidney function, artificial kidney		effects of exercise on physical fitness, food and energy needs	inheritance of characteristics, mutation and effects on man, amnio-centesis, genetic counselling	useful micro-organisms, sewage and disease, safe treatment of sewage, safety precautions in use of micro-organisms, use of insulin in controlling diabetes

Section 2

Aims and Course Objectives

2 Aims and Course Objectives

2 1 Aims

The Standard Grade course in Biology aims to contribute to the general education of pupils through their involvement in the processes of scientific investigation. Through these processes, it is intended that attitudes and abilities such as objectivity and an analytical approach to problems will be fostered. Biology has a particular contribution to make to general education in that it has as its basis the study of living organisms, their interactions and their relationships with the environment. Consequently, the subject should aim to provide pupils with a rational basis for consideration of many of the related issues affecting themselves and society. School courses in Biology should also be concerned with providing an insight into the applications of biological principles to relevant areas of human activity such as health care, environmental management and technology. Biology at Standard Grade offers opportunities for the development of appropriate attributes previously acquired by pupils. The course provides a basis for further study and allows an appreciation of the place of biology in related employment opportunities and in leisure pursuits.

2 2 The Elements

The elements of the course are:

a) Knowledge and Understanding

b) Problem Solving

c) Practical Abilities

d) Attitudes.

Attitudes will not be assessed for certification purposes.

2 3 Course Objectives

As a result of following the course, pupils should acquire:

a) Knowledge and Understanding of

- some biological facts, ideas and techniques
- some applications of biology in society.

b) Skills in problem solving by

- handling and processing information
- evaluating procedures and information
- drawing conclusions and making predictions.

c) Practical abilities associated with investigations in Biology.

d) Positive attitudes such as:

being open-minded and willing to recognise alternative points of view, having an interest in Biology, in themselves and their environment, being aware that they can take decisions which affect the well-being of themselves and others, and of the quality of their environment.

Section 3

Course Content

3 Course Content

3 1 Topic Format

Each topic is described in detail using the following format.

3 1 1 Introduction

This provides the aims and rationale for, and a content outline of, the topic; it indicates whole-course aspects which should be built in, eg investigations, calculations, display of data; and it highlights links between the topic and other curricular areas.

There is also a brief introduction to each sub-topic indicating a recommended teaching approach.

Although a teaching order has been suggested, alternative sequences are not precluded.

3 1 2 Suggested Learning Activities

Essentially, the course is described by the suggested learning activities. Teachers may wish to supplement these, or substitute equivalent activities of their own choosing, where they consider their own material more suited to their particular expertise and to the facilities available.

The suggested learning activities have been selected for the contribution they make to the achievement of the course objectives described in 2 3 under Problem Solving and Practical Abilities.

All the suggested learning activities will contribute in some way to the development of knowledge and understanding. Any additional or alternative activities should also fulfil this requirement of the course.

3 1 3 Learning Outcomes

These describe at two Levels the pupil performance in Knowledge and Understanding required by the course.

The presentation of the Learning Outcomes is a necessary compromise between a large number of very specific statements and a small number of more general statements; because of this, teaching should not be limited to a literal interpretation. The action words used, eg "state" and "identify", are intended for teachers' guidance, to build up a picture of performance expected at different Levels, and should be interpreted as follows:

a) State

Pupils should be able:

- to make a written statement
- to answer correctly an objective test item which requires recall of the item specified.

3 1 3 *(continued)*

b) Give examples

Pupils should be able:

- to give examples as required in the Learning Outcome when the details or the name of the group are stated
- to select an example of the required group from a list of options, eg in an objective test.

c) Identify

Pupils should be able:

- to name or label parts of a diagram, flowchart or model
- to select correct item(s) from a list or from a verbal or pictorial description
- to name the group or groups to which the stated item belongs
- to sequence correctly given steps in a description.

d) Describe

Pupils should be able:

- to give or complete an account, in writing or diagrammatic form, in such a way that the description can be understood.

e) Explain

Pupils should be able:

- to illustrate the meaning of the idea or concept in words and/or diagrams
- to answer correctly an item which tests understanding of that idea
- to give full reasons
- to classify, compare, distinguish between, or list examples of ideas and concepts.

3 2 Topic Descriptions

Topic descriptions for the seven course topics follow on the undernoted pages.

Topic 1: The Biosphere

Introduction

The study of ecology affords an excellent opportunity to fulfil the additional objectives of Standard Grade Biology. The approach is investigative. Knowledge and understanding of ecological principles can be arrived at through the investigation of an ecosystem. Such an investigation allows the development of a variety of experimental and investigatory skills in a fieldwork context. Most pupils possess an interest in living things and a curiosity about "how they work"; this attitude is the major prerequisite for this topic.

There are links with other curricular areas, those with geography being particularly obvious. The approach taken in this topic focuses on the underlying biological principles.

Content Outline

Sub-topic		Summary of Content
a)	Investigating an ecosystem	Sampling and other measurement techniques applied to the investigation of an ecosystem.
b)	How it works	Components of an ecosystem, energy flow, population growth, controlling factors.
c)	Control and management	Intervention in the natural balance of an ecosystem; using understanding to manage ecosystems.

Topic 1: Sub-Topic a – Investigating an Ecosystem

It is intended that this sub-topic should take the form of a practical investigation of an ecosystem. Abiotic factors influencing the distribution and behaviour of organisms and the distribution of the organisms themselves are to be measured, ideally along an environmental gradient.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
1	Make a preliminary visit to an ecosystem.	Identify habitat, animals and plants as the main parts of an ecosystem.	
2	Use appropriate sampling techniques for the ecosystem and organisms studied, eg netting, quadrants, trapping.	Give an example of a technique which might be used for sampling organisms, and describe its use.	Identify a possible source of error that might accompany a sampling technique and explain how it might be minimised.
3	Use simple keys or checklists to identify organisms.		
4	Identify and make measurements of relevant abiotic factors, eg flow rate, moisture, light intensity, pH.	Identify two abiotic factors. Give an example of a technique which might be used to measure an abiotic factor and describe its use.	Identify a possible source of error that might accompany a measurement technique and explain how it might be minimised.
5	Design and carry out an investigation on the effect of abiotic factors on the distribution of an organism using some of the above techniques.		
6	Interpret data on the effect of abiotic factors on the distribution of organisms.	State the effect an abiotic factor has on the distribution of organisms.	Explain possible mechanisms by which abiotic factors might influence the distribution of organisms.

Topic 1: Sub-Topic b – How it Works

This sub-topic considers some of the principles which are applicable to all ecosystems by drawing on the experiences gained during the investigation of an ecosystem. The balance of ecosystems is considered, as are the concepts of energy flow, population growth and controlling factors.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
7	View and discuss material illustrating the components of eco-systems to demonstrate that these are common to all ecosystems.	Describe what is meant by habitat, population, community and ecosystem.	
8	Obtain and present information on producers and consumers.	Describe what is meant by producer and consumer.	
9	Construct food chains and webs using information provided on organisms.	Give an example of both a food chain and food web.	Explain possible effects of the removal of one species on the remaining organisms in a food web.
10	Obtain and present information about energy flow through a food web.	State that the arrows in a food web diagram indicate the direction of energy flow.	
		State 2 ways in which energy can be lost from a food web.	Explain what is meant by the terms pyramid of numbers/biomass.
11	Obtain and present information illustrating the uncontrolled growth of a population. (Use computer modelling if available).	State that the growth rate of a population depends on birth and death rates.	Describe the growth curve of a population under ideal conditions.
12	Discuss possible factors which might limit the growth of a population, eg supply of nutrients and/or water, space, predation, build-up of toxic wastes.	State 3 factors which can limit the growth of a population.	Explain the growth curve of a population under ideal conditions.

Topic 1: Sub-Topic b – How it Works *(continued)*

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
13	Design and carry out an investigation on the effects of competition, eg cress and radish seeds on the same piece of blotting paper.	State that competition occurs when organisms have a need for the same resources. Describe some effects of competition.	
14	View and discuss audio-visual material on the cycling of nutrients.	Explain the importance of nutrient cycles to the organisms of an ecosystem.	Describe the sequence of processes in the nitrogen cycle.

Topic 1: Sub-Topic c – Control and Management

The ability to manage the environment depends on an understanding of the processes involved. Major areas where things can go wrong are noted. An example of one area is considered. The approach in each case is similar. What can go wrong or what has gone wrong is identified and considered in terms of the components of an ecosystem; this leads to possible solutions to particular problems.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
15	Obtain information on main areas in which pollution occurs and identify the sources.	State that pollution affects air, fresh water, sea and land. State that the main sources of pollution are domestic, agricultural and industrial, giving an example of a pollutant from each.	Explain an adverse effect of using fossil fuels and nuclear power as energy sources.
16	Discuss possible measures to reduce pollution, eg alternative energy sources, scrubbing.	Give an example of one way in which pollution may be controlled.	
17	Obtain and present information on the pollution of water by organic waste, to include the effect on oxygen levels and numbers of organisms present.	State that organic waste is a food source for micro-organisms.	Explain the relationship between level of pollution with organic waste, numbers of micro-organisms, oxygen concentration and numbers of species.
		Describe the effect of increased numbers of micro-organisms on the oxygen available to other organisms.	Explain what is meant by "indicator species".
18	Obtain information on problems involving poor management of natural resources and the consequences such as disease and malnutrition.	Give 2 examples of poor management of natural resources and suggest possible improvements. Describe how the effect of poor management of natural resources can produce problems.	Explain how components of an ecosystem are controlled in either agriculture or forestry.

Topic 2: The World of Plants

Introduction

This is a topic which should give pupils a knowledge and understanding of the structure, functioning and uses of plants. It also takes into account the concept of the whole organism in its environment and seeks to strike a balance between the descriptive natural history tradition, to which modern biology owes so much, and the rigorous, detailed study of plant structure and physiology. In such an approach, the attitude of pupils to living things is important and sensitivity to the needs of plants can be encouraged within this topic.

There are ample opportunities for investigations, such as conditions for germination and requirements for photosynthesis. The main focus for attention within the topic is on flowering plants. Some aspects of the topic have links with other subjects in the curriculum, eg uses and economic importance of plants and their products.

Everyday experiences provide a framework for the learning activities. It is hoped that this will encourage an awareness of an interest in plants which may be further developed through leisure pursuits.

Content Outline

Sub-topic		Summary of Content
a)	Introducing plants	Variety, use, commercial exploitation, need for maintaining variety.
b)	Growing plants	Growing plants, germination, sexual reproduction, asexual reproduction.
c)	Making food	Photosynthesis, gas exchange, transport.

Topic 2: Sub-Topic a – Introducing Plants

In this sub-topic, plant variety should be demonstrated and related to practical applications in various industries. Reduced variety could result in a great loss of a natural resource. The plants used could be provided by the pupils themselves.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
1	Examine a variety of flowering and non-flowering plants (at least one from dicotyledons, monocotyledons, conifers, ferns, mosses, fungi and algae).	Give examples of advantages of there being a wide variety of plants.	Explain possible consequences to man and other animals of a reduction in the variety of species.
2	Obtain and present information on uses of plants by humans (raw materials, foods, medicines).	Describe 3 specialised uses of plants.	Describe a production or refining process, eg malting barley, rape seed, raspberries, timber. Describe two potential uses of plants or plant products eg new medicines, new food sources.

Topic 2: Sub-Topic b – Growing Plants

There is the possibility of carrying out a variety of investigations in this sub-topic. There are opportunities to have inter-pupil cooperation in terms of collecting and collating results from a range of experiments and investigations. The relationship between structure and function should be emphasised rather than details of plant anatomy for its own sake. The important process of sexual reproduction is described in the context of seed production and propagation of new varieties. Important strains of plants can be preserved by employing forms of artificial propagation; natural asexual reproduction is also studied.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
3	Examine the structure of a dicotyledon seed (broad bean).	Describe the functions of three main parts of the seed of a dicotyledon, ie seed coat, embryo, food store.	
4	Design and carry out investigations on the conditions necessary for germination.	Describe the effect of temperature and the availability of water and oxygen on germination.	Describe the changes in percentage germination that occur over a range of temperatures.
5	Examine the flowers (including pollen and ovules) of a wind-pollinated and an insect-pollinated flower.	Describe the functions of the parts of flowers, ie sepal, petal, stamen, anther, stigma, ovary, nectary.	Explain the structure of wind- and insect-pollinated flowers in relation to sexual reproduction.
		Describe methods of pollination.	Describe the growth of the pollen tube and fusion of gametes.
		Describe fertilisation and fruit formation.	
6	Examine fruits and seeds to observe the variety of dispersal mechanisms.		Describe one example of each of the following different dispersal mechanisms: wind, animal – internal, animal – external.
7	Take cuttings from a variety of flowering plants.	Describe ways of propagating flowering plants artificially by cuttings and grafting.	Explain the advantages to man of artificial propagation in flowering plants.
			Describe what is meant by the term “clone”.
8	Observe a range of natural structures involved in plant asexual reproduction.	Describe asexual reproduction by runners and tubers.	Describe the advantages of both sexual and asexual reproduction to plants.

Topic 2: Sub-Topic c – Making Food

This sub-topic examines plant requirements and how these are obtained and used in making food. In the examination of leaves, the emphasis is on gas exchange surfaces. Opportunities exist for collaborative investigations.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
9	Demonstrate the movement of materials in plant stems.	Explain the need for transport systems in a plant. Describe the pathways of movement of water and food in xylem and phloem.	Describe the structure of phloem and xylem and identify other functions of the transport system.
10	Examine the gross and microscopic structure of a plant leaf.	State that plants take in carbon dioxide from the air through stomata which can open and close.	Describe the external features and internal structure (epidermis, mesophylls, veins) of a leaf in relation to its function in gas exchange.
11	Carry out an investigation into the loss of water from a plant.	State that water vapour is lost through stomata.	
12	Test leaves for starch.	State that green plants make their own food which may be stored as starch.	Describe the fate of carbon dioxide as structural and storage carbohydrates in plants and as energy sources.
13	Design and carry out investigations on the requirements for photosynthesis (need for chlorophyll, for light energy and for carbon dioxide).	State that green plants convert light energy to chemical energy using chlorophyll.	
		Describe the process of photosynthesis in terms of raw materials and products.	Explain what is meant by a limiting factor and describe the main limiting factors in the process of photosynthesis.

Topic 3: Animal Survival

Introduction

All living organisms have particular requirements to ensure survival and reproduction. In this topic, three aspects of the needs of animals provide contexts for learning activities and investigations by pupils. The areas for study are food, its importance and utilisation; sexual reproduction, including the process of fertilisation and particular adaptations to ensure successful development of the young; ways in which the body regulates an internal water balance and removes nitrogenous waste products. The emphasis in three of the sub-topics is on systems in vertebrates and particularly in mammals. The final sub-topic illustrates ways in which animals respond appropriately to changes in the environment.

This topic seeks to develop particular aspects of pupils' experience of both variety of animals and their needs. There are opportunities to compare vital processes of animals with those of plants studied in other topics.

The sub-topic "The need for food" has links with other curricular areas such as Home Economics.

Content Outline

Sub-topic		Summary of Content
a)	The need for food	Nature of food, requirements for major types, food ingestion, digestion and absorption in a mammal.
b)	Reproduction	Mating and fertilisation in fish and mammals, reproductive organs in mammals, protection of the embryo, care of young.
c)	Water and waste	Need for maintaining internal waterbalance, removal of waste, functioning of the kidney, application to maintenance of human health.
d)	Responding to the environment	Effect of environmental factors on behaviour.

Topic 3: Sub-Topic a – The Need for Food

This sub-topic establishes animals' need for food. The major food types and their functions are introduced as a prelude to a study of the need for the process of digestion. Experimental investigations of the role of digestive enzymes leads to an appreciation of some detail of absorption and transport of simple molecules.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
1	Obtain and present information on carbo-hydrates, proteins and fats.	Explain in simple terms why food is required by animals.	State the chemical elements present in carbohydrates, proteins and fats. Describe the simple structure of carbohydrates, proteins and fats in terms of simple sugars, amino acids, fatty acids and glycerol.
2	Obtain information on the principle of digestion.	State that digestion is the breakdown of large particles of food into smaller particles to allow absorption into the blood stream through the small intestine wall.	Explain that digestion involves the breakdown of insoluble food substances into soluble food substances.
3	Examine dentition in skulls of a herbivore, a carnivore and a human.	Describe the role of different types of teeth in the mechanical breakdown of food in a herbivore, a carnivore and an omnivore such as a human.	
4	Examine the gross structure of the mammalian alimentary canal and associated organs.	Identify in a diagram/model the main parts of the mammalian alimentary canal and associated organs (mouth, salivary glands, oesophagus, stomach, pancreas, liver, gall bladder, small intestine, large intestine, appendix, rectum and anus).	State the sites of production of the main digestive juices in a mammal (salivary glands, stomach, pancreas, liver, small intestine). Explain the mechanism of peristalsis. Explain how the contractions of the stomach help in the chemical breakdown of food.

Topic 3: Sub-Topic a – The Need for Food *(continued)*

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
5	Design and carry out investigations on the effect of digestive enzymes.	State that different enzymes are responsible for the breakdown of carbohydrates, proteins and fats.	Give an example of an amylase, a protease and a lipase. State their substrates and products.
6	Examine a cross-section of the small intestine wall of a mammal.	Explain how the structure of the small intestine is related to its function.	Explain how the structures of a villus, including the lacteal and the blood capillaries, are related to the absorption and transport of food.
7	Obtain and present information on the function of the large intestine.	Describe the role of the large intestine in water absorption and elimination.	

Topic 3: Sub-Topic b – Reproduction

Pupils should be aware that selection favours those individuals that leave most surviving offspring. This sub-topic provides opportunities for pupils to investigate ways in which animals achieve this through sexual reproduction. Aspects to be considered are the achievement of fertilisation, protection of the developing embryo and care of the young.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
8	Examine sperm and eggs to identify main features.	Describe the main features of sperm and eggs.	
9	Obtain information on mating and fertilisation in a fish and a mammal.	State that in some fish, sperm are deposited in water adjacent to the eggs and that in mammals, sperm are deposited in the body of the female. Describe the process of fertilisation.	Explain the importance of internal fertilisation to land-living animals.
10	Observe the general structure of the male and female reproductive organs of a mammal.	State that sperm cells are produced in the testes. State that eggs are produced in ovaries and are released into oviducts, where fertilisation takes place.	
11	Observe stages in the development of fertilised eggs in fish and mammals.	State that in fish, eggs are protected by flexible coverings and that the embryos obtain food from enclosed yolk.	Explain the relationship between the number of eggs/ young produced and the degree of protection afforded during fertilisation and development in fish and mammals.
		Describe how the fertilised egg passes down the oviduct and becomes attached to the wall of the uterus, develops in fluid of the amniotic sac and obtains food from the maternal circulation.	Describe the structure and function of the placenta.
12	Observe subsequent development of young in fish and mammals.	State that in a fish, like the trout, the young emerge from the eggs able to maintain themselves. State that at birth, the young of mammals are dependent on the adult for care and protection.	

Topic 3: Sub-Topic c – Water and Waste

This sub-topic focuses on the need to maintain an internal water balance and to remove poisonous wastes from the body. The structure and functioning of the mammalian kidney in relation to these needs is explored. Some relevant applications to the maintenance of human health are considered.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
13	Obtain information on gain and loss of water in a mammal.	Identify the ways in which a mammal gains and loses water.	
14	Carry out calculations on water balance in the body and construct a daily water table.	State that the kidneys are the main organs for regulating the water content in a mammal.	Explain the role of ADH in the regulation of water balance.
15	Examine the urinary system of a mammal, including the gross structure of the kidneys.	Identify the positions, and state the functions, of: the kidney, renal arteries and veins, ureter, and bladder.	
		State that essential kidney functions are filtration of blood and reabsorption of useful materials such as glucose.	Explain the process of urine production using a simple diagram of the nephron, to include the Bowman's capsule, glomerulus, blood capillaries and collecting duct.
		State that urea is a waste product removed in the urine.	State the source of urea in the body and describe how urea is transported to the kidneys.
16	Compare the action of the kidneys and of a kidney machine to illustrate the main steps in the process of urine production.	Explain the implications of damage to the kidneys by accidents or disease.	Describe the relative benefits and limitations of replacement and "artificial" kidneys.

Topic 3: Sub-Topic d – Responding to the Environment

This sub-topic highlights how some organisms responds to environmental stimuli by behaviour which helps to ensure survival.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
17	Design and carry out an investigation on the effect of one environmental factor on the behaviour of an animal, eg response of water scorpions, blowfly maggots, *Daphnia*, woodlice or fruit flies to light; response of *Paramecium* or planarians to chemicals and response of woodlice to humidity.	Give examples of environmental factors which affect behaviour. Describe the response of an animal to change in one environmental factor.	Explain the significance of given examples of response to environmental stimuli in the life of the organism concerned.
18	Interpret data on rhythmical behaviour to identify external trigger stimulus, cycle of activity and significance to species, eg migration, response to tidal rhythms.	Describe examples of rhythmical behaviour and in each case identify the external trigger stimulus.	Explain the significance of given examples of rhythmical behaviour in the life of the organism concerned.

Topic 4: Investigating Cells

Introduction

The aim of this topic is to stress the unity of life by developing a knowledge and understanding of those structures and processes shared by all living organisms. The content identifies the facts and principles which are fundamental to the pupils' knowledge and understanding of the cell as the structural and functional unit of life.

Many of the facts, principles and skills acquired by pupils during the study of this topic, and from earlier experience in science, will provide links with other topics in the course as well as a basis for further studies.

It is important that the teaching approach adopted takes account of and seeks to develop the interest and curiosity of pupils in the existence of living things which are not visible to the naked eye.

Content Outline

Sub-topic		Summary of Content
a)	Investigating living cells	Structural similarities and differences between plant and animal cells.
b)	Investigating diffusion	Diffusion, osmosis.
c)	Investigating cell division	Mitosis.
d)	Investigating enzymes	Catalysts, enzymes, effect of temperature/pH on enzyme action; breakdown and synthesis by enzymes.
e)	Investigating aerobic respiration	Aerobic respiration.

Topic 4: Sub-Topic a – Investigating Living Cells

Examination, with microscopes, of sections of animal and plant tissues, leads pupils to an awareness of the cellular structure of living organisms. The approach adopted should be investigatory. Skills related to the preparation of specimens for microscopic examination should be developed, and observational and drawing skills encouraged. Pupils will acquire a better knowledge and understanding of cells by working with and observing living tissues than from text book diagrams and drawings.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
1	Examine the micro-scopic structure of living tissue to observe its cellular nature, eg *Elodea* leaf, potato tissue.	State that cells are the basic units of living things.	
2	Stain cells for micro-scopic examination.	Explain the purpose of staining animal and plant cells.	
3	Use a microscope to examine stained animal and plant cells.	Describe the structural similarities of and differences between animal and plant cells.	

Topic 4: Sub-Topic b – Investigating Diffusion

The aim of this sub-topic to promote a knowledge and understanding of the process of diffusion and osmosis. Experiments and demonstrations which illustrate diffusion should open up discussion of this phenomenon. The designing of simple experiments to test pupils' ideas should be encouraged.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
4	Carry out investigations on the process of diffusion.	State that a substance can diffuse from a high concentration to a low one.	Explain the importance of diffusion to organisms.
5	Design and carry out investigations on diffusion using cell models made from Visking tubing, eg diffusion of starch and glucose.	Give examples of substances which enter and leave the cell by diffusion, eg dissolved food, oxygen, carbon dioxide and water. State that the cell membrane controls the passage of substances into and out of the cell.	
6	Obtain information on osmosis in plants and animals.	Identify osmosis as a "special case" of the diffusion of water.	Explain osmosis in terms of a selectively permeable membrane and of a concentration gradient.
7	Design and carry out investigations into the response of plant cells to different concentrations of saline or sucrose solutions.		Explain observed osmotic effects in plants and in animal cells in terms of the concentration of water in the solutions involved.

Topic 4: Sub-Topic c – Investigating Cell Division

This sub-topic seeks to develop pupils' knowledge and understanding of the process of mitotic cell division, providing an opportunity for all pupils to demonstrate their skills in obtaining and presenting information about chromosome behaviour during cell division. Knowledge and understanding acquired will provide a basis for further studies, eg in the Inheritance topic.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
8	Obtain and present information about cell division from audio-visual aids, photographs and drawings, eg of *Amoeba, Pleurococcus*, root tip.	State that cell division is a means of increasing the number of cells in an organism. State that the nucleus of the cell controls cell activities including division.	
9	Obtain and present information on chromosome behaviour during mitosis.	State that each of the two cells produced by cell division has a complete set of chromosomes and the same information.	Describe the stages of mitosis. Explain why it is important that the chromosome complement of daughter cells in multicellular organisms is maintained.
10	Arrange drawings or diagrams of the stages of mitosis in the correct sequence.	Identify the correct sequence of stages of mitosis.	

Topic 4: Sub-Topic d – Investigating Enzymes

The aim of this sub-topic is to provide a basis of knowledge and understanding which can be developed further in the Biotechnology topic. Pupils should know that cells produce enzymes and that many cellular processes depend upon the activity of enzymes. This activity can be affected by changes in factors such as temperature and pH. Pupils should understand the specific relationship between an enzyme and its substrate. This sub-topic forms a suitable vehicle for developing those skills related to practical abilities and problem solving.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
11	Carry out an investigation on the catalase reaction when plant and animal tissues are added to hydrogen peroxide solution.	Explain why enzymes are required for the functioning of living cells. Explain the meaning of the term "catalyst".	Explain the term "specific" as applied to enzymes and their substrates.
12	Carry out an investigation on the effect of non-human amylase on starch.	Give an example of an enzyme involved in the chemical breakdown of a substance.	
13	Carry out an investigation on the action of potato phosphorylase on glucose-l-phosphate.	Give an example of an enzyme involved in synthesis.	
14	Design and carry out investigations on the effect of changes in pH and in temperature on enzyme activity.	State that enzymes are proteins.	
		Describe the effect of temperature on enzyme activity. Describe the effect of a range of pH on the activity of pepsin and catalase.	Explain the term "optimum" as applied to the range of conditions in which enzymes operate.

Topic 4: Sub-Topic e – Investigating Aerobic Respiration

Respiration is a cellular process. Pupils should understand the cell's need for energy and should have a basic knowledge and understanding of how energy is released from food in the presence of oxygen.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
15	Obtain and present information on the uses of energy by living cells.	State three reasons why living cells need energy.	
16	Design and carry out an investigation on the energy content of food.		State that fats and oils contain more chemical energy per gram than carbohydrates or protein.
17	Carry out an investigation on the uptake of oxygen by living tissue, eg in germinating seeds.	State that cells need oxygen to release energy from food during aerobic respiration. Describe aerobic respiration in terms of a word equation.	
18	Design and carry out an investigation on the release of carbon dioxide by respiring tissue.	State that carbon dioxide is given off by cells during tissue respiration and is derived from food.	
19	Design and carry out an investigation on the release of heat energy from respiring tissue.	State that heat energy may be released from cells during respiration.	Explain the importance of energy released from food during respiration to the metabolism of cells.

Topic 5: The Body in Action

Introduction

This topic serves as an introduction to some of the biological principles involved in the study of human movement and physical performance. It is intended that pupils will acquire knowledge and understanding of a range of processes associated with movement and of the relationships between physical activity and healthy living. Opportunities for investigatory activities by pupils are provided throughout the topic; whenever possible these activities should include first-hand observation and experience of the human body in action.

It is anticipated that the pupils will have some previous experience of related learning activities. Some of the principles will be pursued elsewhere in the course, eg in Animal Survival and in Investigating Cells.

Throughout the teaching of the topic, the emphasis is on an understanding of the principles involved and how these principles relate to performance.

Content Outline

Sub-topic		Summary of Content
a)	Movement	The relationship of muscles, skeleton and associated structures in the performance of physical activities.
b)	The need for energy	The contribution of the respiratory and circulatory systems to providing energy for muscular activities.
c)	Coordination	Receiving and processing information in the coordination of movement responses.
d)	Changing levels of performance	Some effects of repeated physical activity.

Topic 5: Sub-Topic a – Movement

The purpose of this sub-topic is to provide a background to the primary requirements of physical activity, ie support and movement. It is intended to provide some understanding of how movement is achieved, of the range of movement which is normally available and of the application of these to physical activities.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
1	Observe a range of human activity from life or from audio-visual material to identify requirements for movement, eg examples from sports, dance, play and work.		
2	Observe a human skeleton or a model.	State that the skeleton provides a framework for support and muscle attachment. State that the skeleton protects the heart, lungs, brain and spinal cord.	
3	Observe the movement at a ball and socket joint and hinge joint, eg hip, knee.	Describe the range of movements allowed by a ball and socket joint and by a hinge joint. State the functions of ligaments and cartilage at a joint.	Describe the structure of a synovial joint and state the functions of its parts.
4	Carry out an investigation on the composition of bone.	State that bone is composed of flexible fibres and hard minerals.	State that bone is formed by living cells.
5	Examine the gross structure of the limb of a mammal, eg rabbit.	State that muscles are attached to bones by tendons.	Explain why tendons are inelastic.
6	Examine a model or specimen to observe the action of muscles.	Describe how movement is brought about by muscle contraction.	Explain the need for a pair of opposing muscles at a joint.

Topic 5: Sub-Topic b – The Need for Energy

The purpose of this sub-topic is to give pupils the opportunity to investigate systems of the body which provide muscles with the energy resources which they require in producing movement. This involves investigation of the structure of the respiratory and circulatory systems and how these structures function in meeting the energy requirements of muscles.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
7	Obtain information on energy content of a range of foods and relate this to the energy expenditure in a range of activities.	State the effects of the imbalance between energy input and output.	
8	Obtain information on the composition of inhaled and exhaled air.	State that oxygen is absorbed and carbon dioxide released in breathing.	
9	Examine lungs and associated structures of a mammal.	Describe the internal structure of the lungs.	Describe the mechanism of breathing in humans. Explain the function of cilia, cartilage and mucus in the trachea and bronchi. Describe gas exchange between the air sacs and the surrounding blood vessels. Describe the features which make lungs efficient gas exchange structures.
10	Examine the heart and associated blood vessels of a mammal.	Identify the four chambers of the heart. Describe the path of blood flow through the heart and its associated blood vessels. Describe the positions and function of the heart valves. Explain the difference in thickness of the walls of the ventricles. State that the heart obtains its blood supply from coronary arteries.	

Topic 5: Sub-Topic a – Movement *(continued)*

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
11	Obtain information on the relationship between arteries, veins and capillaries.	State that blood leaves the heart in arteries, flows through capillaries and returns to the heart in veins. State that the pulse indicates that blood is flowing through an artery.	
12	Examine the micro-scopic structure of mammalian blood using prepared slides.	Describe the function of red blood cells and plasma in the transport of respiratory gases and food. Describe gas exchange between the body cells and the surrounding capillaries.	Explain the function of haemoglobin in the transport of oxygen. Describe the features of a capillary network which allow efficient gas exchange.

Topic 5: Sub-Topic c – Coordination

The purpose of this sub-topic is to provide understanding of the components of coordination which apply to physical activity.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
13	Observe a simple activity, eg skipping, to identify the components of coordination.		
14	Carry out an investigation to compare monocular and binocular vision, eg ring throwing, threading a needle.	State that judgement of distance is more accurate using two eyes rather than one.	Explain the relationship between judgement of distance and binocular vision.
15	Examine the gross structure of a mammalian eye.	Identify the cornea, iris, lens, retina, optic nerve and state their functions.	
16	Carry out an investigation into directional hearing.	State that judgement of direction of sound is more accurate using two ears rather than one.	
17	Examine a model ear to identify structures involved in hearing and balance.	Identify the ear drum, middle ear bones, cochlea, auditory nerve and semi-circular canals and state their functions.	Explain how the arrangement of semi-circular canals is related to their function.
18	Examine the gross structure of the nervous system of a mammal.	State that the nervous system is composed of the brain, spinal cord and nerves.	
19	Obtain and present information on the flow of information in the nervous system.	State that the nerves carry information from the senses to the central nervous system and from the central nervous system to the muscles.	Describe how a reflex action works, using a simple model of a reflex arc. State that the central nervous system sorts out information from the senses and sends messages to those muscles which make the appropriate response.
20	Obtain and present information on the three main parts of the brain.		Identify the cerebrum, cerebellum and the medulla and state their functions in simple terms.

Topic 5: Sub-Topic d – Changing Levels of Performance

The purpose of this sub-topic is to allow pupils to measure some physiological changes resulting from physical activity, and to use these as indicators of level of performance and of fitness.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
21	Carry out an investigation to demonstrate muscle fatigue, eg measurement of repeated hand grip, finger lifting.	State that continuous or rapidly repeated contraction of muscle results in fatigue.	
		State that muscle fatigue results from a lack of oxygen and a build up of lactic acid.	Explain muscle fatigue in terms of anaerobic respiration.
22	Carry out an investigation to demonstrate the effect of exercise on pulse rate or breathing rate.	Explain why pulse rate and breathing rate increase with exercise.	
23	Obtain and analyse information on the effects of exercise and on recovery rates in athletes and non-athletes.	State that with exercise the pulse rate, breathing rate and lactic acid level rise less in an athlete than in an untrained person.	
		State that recovery time is the time taken to return to normal levels of pulse rate, breathing rate and lactic acid.	State that training improves the efficiency of the lungs and circulation.
		Describe how recovery time can be used as an indication of physical fitness.	Explain the relationship between the effects of training and recovery time.

Topic 6: Inheritance

Introduction

The simple observation of similarities and differences between individual organisms is taken as the starting point for the study of inheritance, a subject which has enormous economic and social importance. A knowledge of the processes of plant and animal breeding has brought about revolutions in agriculture, producing more and more specialised organisms which give bigger and better yields. In understanding the mechanisms behind the breeding, man has approached closely the point where manipulation of the controlling chemicals brings the potential to predict and control changes in organisms. Crop disease and pest control have become increasingly important.

Throughout the topic, the opportunity should be taken to encourage the use of calculation and the display of data.

This topic has links with several parts of the course but principally the topics of "The Biosphere", "The World of Plants", "Animal Survival" and "Investigating Cells". In many respects, the ideas involved in these topics are a necessary preparation for this part of the course. While it is not a pre-requisite of the topic "Biotechnology", it is hoped that this work will allow for a deeper understanding of the uses of genetic manipulation.

There may be a benefit in consulting with geography departments on aspects relating to man's use of resources.

Content Outline

Sub-topic		Summary of Content
a)	Variation	The species, variation and survival value.
b)	What is inheritance?	Particulate nature of inheritance, patterns in inheritance and use of organisms; fertilisation and chromosome numbers; sex determination.
c)	Genetics and society	Detection of genetic abnormalities; breeding of selected plants and animals; mutations.

Topic 6: Sub-Topic a – Variation

This sub-topic reinforces work on variation and extends these ideas by considering, in a number of species, examples of variation.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
1	Obtain and present information to illustrate what is meant by the term "species".	State that a species is a group of interbreeding organisms whose offspring are fertile.	
2	Visit zoo, natural history museum, botanic gardens or fieldwork site, to observe a variety of species.	State that variation can occur within a species.	
3	Design and carry out investigations on variation in various organisms, eg ray florets in daisies, size and shape in leaves, height and diameter of limpets.	Give examples of continuous and discontinuous variation.	Explain what is meant by continuous and discontinuous variation.

Topic 6: Sub-Topic b – What is Inheritance?

This sub-topic aims to introduce the idea of the physical basis of inheritance. Throughout, only monohybrid crosses are considered. In referring to fertilisation, the main aim is to reinforce the notion of gametes as links between generations. The determination of sex also illustrates the passage of genetic information from one generation to the next, together with the need to obtain material from both parents.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
4	Obtain and present information on particular inherited characteristics, eg tongue rolling, red hair, leaf shape, flower colour.	State that certain characteristics are determined by genetic information received from the parents and give examples, from animals and plants.	
5	Obtain and present information on the characteristics of parents and offspring, possibly using monohybrid crosses.	Identify examples of phenotypes of the same characteristic. Identify examples of true-breeding, dominant and recessive characteristics from the numbers and phenotypes of given crosses.	
6	Interpret data to establish patterns in the number of phenotypes appearing in the first and second filial generations.	Identify generations as P, F_1 and F_2 from given examples of crosses. State that the phenotypes of the F_1 in a true-breeding cross are uniform.	State that the parents in experimental monohybrid crosses are usually true-breeding and show different phenotypes of the same characteristic.

Topic 6: Sub-Topic b – What is Inheritance? *(continued)*

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
7	View and discuss audio-visual materials on chromosomes behaviour during gamete formation and fertilisation in plants and animals.	State that each body cell has two matching sets of chromosomes. State that sex cells are called gametes. State that the reduction of the number of chromosomes to a single set occurs during gamete formation. State that each sex cell carries one set of chromosomes. Describe how a complete double set of chromosomes is achieved at fertilisation.	Predict the proportions of the phenotypes of the F_2 offspring of a monohybrid cross.
8	Examine diagrammatic representations of genotypes in monohybrid crosses.	State that genes are parts of chromosomes State that a characteristic is controlled by two forms of a gene. State that each parent contributes one of the two forms. State that each gamete carries one of the two forms of the gene. State the meaning of the word genotype.	State that different forms of a gene are called alleles. Explain monohybrid crosses in terms of genotypes. Explain differences between observed and predicted figures in monohybrid crosses.

Topic 6: Sub-Topic b – What is Inheritance? *(continued)*

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
9	Obtain and present information on sex determination in humans.	State that the sex of a child is determined by specific chromosomes called X and Y chromosomes. State that in humans, each male gamete may have an X or a Y chromosome, while each female gamete has an X chromosome. Explain how the sex of a child is determined with reference to X and Y chromosomes.	

Topic 6: Sub-Topic c – Genetics and Society

This sub-topic illustrates improvements to plant and animal stocks, and the impact of a knowledge of genetics on matters relating to human inheritance.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
10	Obtain and present information on the controlled breeding of organisms and its importance to man, eg increased yield, disease resistance.		
11	Analyse and interpret data on characteristics of selected varieties.	Give two examples of an improved characteristic resulting from selective breeding, eg increased yield, increased disease resistance, or increased growth.	Describe two examples, one plant, one animal, of the enhancement of a characteristic through selective breeding.
12	Obtain and present information on chromosome mutations and their effects on man and other organisms.	Describe one example of a human condition caused by a chromosome mutation, eg Down's Syndrome.	Give an example of a chromosome mutation, advantageous to man, in a plant or animal of economic importance.
		State that amniocentesis can be used to detect chromosome characteristics before birth.	Give an example of a factor which can influence the rate of mutation in an organism.

Topic 7: Biotechnology

Introduction

Biotechnology – the application of biological processes in industry – is at the heart of a scientific revolution whose impact on every day life may rival that of the micro-electronics industry. Though pupils may at the moment be familiar only with the products of the traditional biotechnological processes – bread, alcohol, cheese, yoghurt, etc – teachers can already point to the increased use in the home of biological detergents and antibiotics, and look forward to an imminent increase in the world's use of biotechnologically produced fuels and chemicals for health care products.

It is intended that pupils will gain knowledge and understanding of at least some of the scope of biotechnology and of the principles on which biotechnology is based. This topic is concerned solely with the activities of microbes, but teachers may wish to refer to other organisms.

Pupils' attention is directed to the kinds of problems for mankind which biotechnology can help to solve. Through a series of practical, laboratory-based activities, pupils should be allowed to manufacture and use some of the products of living organisms.

The first two sub-topics are based on the idea of harvesting products from organisms and the need to process waste materials. These sub-topics pave the way for the more difficult concepts of manipulating organisms and redirecting biological processes.

This topic allows teachers to draw on previous study of ecosystems, metabolic processes and heredity, and perhaps to direct pupils' attention to possible job opportunities in biotechnology, and to related leisure activities.

Content Outline

Sub-topic		Summary of Content
a)	Living factories	Fermentation and its products.
b)	Problems and profit with waste	Decomposition and upgrading of waste.
c)	Reprogramming microbes	Application of genetic engineering.

Topic 7: Sub-Topic a – Living Factories

Pupils should be familiar with the idea that man has traditionally made use of a wide range of products from plants and animals. A brief discussion of some of these could be used to introduce the idea of harvesting metabolic products of organisms whose tiny size makes them less familiar. Their products, however, are found in every home. The opportunity presents itself here to investigate briefly the structure and requirements of the micro-organisms involved.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
1	Make bread and/or ferment the juice of suitable fruit.	State that the raising of dough and the manufacture of beer and wine depend on the activities of yeast.	
2	Using a microscope, examine yeast from fermented fruit juice and from "bloom" on a grape.	Identify yeast as a single-celled fungus, which can use sugar as food.	
3	Carry out investigations on the production of carbon dioxide, ethanol and heat by living yeast.	Using a word equation, state the process of fermentation of glucose by yeast.	Describe the process of anaerobic respiration and compare it will aerobic respiration.
4	Obtain information about commercial brewing practices.		Describe how commercial brewers provide the best growing conditions for yeast. Explain what is meant by the term "batch processing".
5	Design and carry out an investigation on the effect of germination on the starch in barley grains.		Explain the need for malting of barley before use by the brewing industry.
6	Make cheese and/or yoghurt.	State that the manufacture of cheese and yoghurt depends on the activities of bacteria.	
7	Design and carry out an investigation on the changes which take place in the pH of souring milk.	State that the souring of milk is a fermentation process.	Explain the souring of milk in terms of bacterial fermentation of lactose.

Topic 7: Sub-Topic b – Problems and Profit with Waste

Whenever man disposes of waste, he risks causing problems to himself and to his environment. This sub-topic deals briefly with such problems which can arise from the need to dispose of sewage, and then looks at how biotechnology helps to eliminate these problems by harnessing the natural process of decay (the biggest single application of biotechnology).

From another point of view, simply to dispose of waste may be to neglect valuable resources, so the sub-topic deals with those aspects of biotechnology which allow the recycling/upgrading of waste.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
8	Interpret data on chemical and biological changes caused by sewage disposal, eg untreated into a river.	Describe some examples of the damage caused to the environment by disposal of untreated sewage. Give examples of diseases which may be spread by untreated sewage.	
9	Demonstrate in the course of practical work, the principal precautions to be taken when working with micro-organisms.	Describe the principal precautions to be taken during laboratory work with micro-organisms. Explain the importance of such precautions in biotechnological processes whenever relevant.	Explain the precautions which are taken during manufacturing processes with reference to resistant fungal and bacterial spores.
10	Design and carry out an investigation on the decomposition of a range of organic substrates.		Describe the part played by bacteria in the process of decay and recycling of carbon and nitrogen. Explain the process of decay in terms of the energy requirements of micro-organisms.
11	Obtain information from a variety of sources, which might include a visit to a sewage treatment plant, and complete partially drawn flow diagrams.	State that the main process in the treatment of sewage is its breakdown by the action of decay micro-organisms to products harmless to the environment.	Explain why complete breakdown of sewage is only possible in aerobic conditions.
		Describe how the oxygen required by micro-organisms can be provided during sewage treatment.	Explain why a range of micro-organisms is needed to break down the range of materials in sewage.

Topic 7: Sub-Topic b – Problems and Profit with Waste *(continued)*

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
12	Obtain and present information on modern biotechnological methods of upgrading waste or excess materials through-out the world.	Give 2 examples of useful products and the waste materials from which they are gained through the action of micro-organisms and explain the economic importance of this technology.	Explain the advantages of upgrading waste in terms of increasing its available energy or protein levels.
13	Demonstrate the burning of alcohol or methane.	State that alcohol and methane are products of fermentation. Explain the advantages of deriving fuel through fermentation rather than from fossil sources.	
14	Interpret data on the growth rate of micro-organisms and their efficiency in protein production compared with plants and animals. (Data may be provided by interactive computer simulations and/or a demonstration of single-celled protein and/or single-celled oil production.)	State that under suitable conditions, micro-organisms can reproduce very rapidly by asexual means. State that micro-organisms may be harvested to provide protein rich food for animals or man.	

Topic 7: Sub-Topic c – Reprogramming Microbes

Much of the thrust of modern biotechnology comes from man's ability to manipulate the essential life processes of organisms. This is likely to be appreciated by most pupils at only a very elementary level. However, the way has to some extent been prepared in previous sub-topics by reference to selection and breeding of micro-organisms. On the other hand, pupils will readily understand the ever-increasing prominence of the products of this technology which are gradually replacing those from traditional sources. This sub-topic provides the opportunity for pupils to become familiar with a few of these products, while they continue to develop their skills of investigation and experimental design.

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
15	Obtain and present information on genetic engineering.	State that the normal control of bacterial activity depends on its chromosomal material.	Explain genetic engineering in terms of manipulation of chromosomal material.
16	Construct simple models of bacterial cells to illustrate the technique of genetic engineering.	State that pieces of chromosome can be transferred from a different organism and so allow bacteria to make new substances.	State that as a result of genetic engineering, bacteria may produce increased quantities of products and speed up processes. Explain some of the advantages of genetic engineering, compared with selective breeding, in producing new genotypes to create the best organism for a particular function.
17	List biotechnological products in everyday use.		
18	Obtain information (possibly through use of interactive computer programs) on the principle of changing a cell's instructions to make it behave in a new way.	Give some examples of the products of genetic engineering and their applications, eg insulin.	Explain the ever increasing need for insulin produced by biotechnology.
19	Discuss the potential hazards of creating new strains of bacteria.		

Topic 7: Sub-Topic c – Reprogramming Microbes *(continued)*

	SUGGESTED LEARNING ACTIVITIES	LEARNING OUTCOMES (KNOWLEDGE AND UNDERSTANDING)	
		GENERAL LEVEL Grades 4, 3	CREDIT LEVEL Grades 2, 1
			In addition
20	Design and carry out an investigation on the action of "biological" detergents, eg on agar or stained material.	State that "biological" detergents contain enzymes produced by bacteria.	Describe the advantages of using the low-temperature enzyme reactions of "biological" detergents. Explain the action of "biological" detergents in terms of digestion by enzymes.
21	Design and carry out an investigation on the action of "biological" and "non-biological" detergents at different temperatures.		
22	Design and carry out an investigation on the action of antibiotic discs.	State that an antibiotic is a chemical which prevents growth of micro-organisms.	Explain why a range of antibiotics is needed in the treatment of bacterial diseases.
23	Using simple experiments, demonstrate the technique of immobilization, especially of whole organisms, eg yeast.		Describe the advantages of using immobilization techniques. Explain how continuous-flow processing is allowed by using immobilization and the advantages this has over batch processing.

Section 4

Assessment for Certification

4 Assessment for Certification

4 1 Certification

A grade for attainment in each assessable element will be recorded on the Certificate, together with an overall grade awarded for the course derived from the mean of the element grades, with a weighting of 2:2:1 in favour of the externally assessed elements. For Biology, element grades will be awarded on the scale 5 to 1, Grade 1 denoting the highest performance. Grade 6 is not available for an element, but may be gained in the overall aggregated award. Grade 7 is available (see 4 4 below).

4 2 Assessment Scheme

The assessment of pupil performance in the three elements – Knowledge and Understanding, Problem Solving and Practical Abilities – will be carried out with reference to the Extended Grade Related Criteria defined for each of these elements.

Knowledge and Understanding and Problem Solving will be assessed externally by a written examination.

Practical Abilities will be internally assessed with external moderation.

4 3 External Assessment

An examination paper in Knowledge and Understanding and Problem Solving will be set at each of General and Credit Levels. The papers will be designed to assess the achievement of the course objectives relating to these two elements. All course topics will be examinable. The context of, and the standard of performance required in, the questions will be appropriate to the Level to which each paper relates. The Credit Level paper will also include a number of questions relating to General Level Learning Outcomes.

Both the General Level paper (assessing Grades 4 and 3) and the Credit Level paper (assessing Grades 2 and 1) will be of 1½ hours' duration. Each paper will contain multiple choice items, short-answer questions, extended-answer questions and interpretation questions. Grade 5 will be awarded to candidates who narrowly fail to meet the criteria for General Level.

Marks will be allocated to each question and a total mark obtained for the appropriate element. The two grades associated with each Level will be distinguished by setting two cut-off scores. The lower score (in the region of 40-50%) will reflect a satisfactory overall standard of performance, the upper score (in the region of 70-80%) a high overall standard of performance.

Candidates who attempt papers at both Levels will be given the better of the two grades achieved on the external papers. Performance at one Level will **not** be taken into account in grading at the other Level.

4 4 Grade 7 and No Overall Award

For any element, Grade 7 will indicate that the candidate has, in the element concerned, completed the course but has not fulfilled the requirements for Grade 5 or better.

The Scottish Qualifications Authority (SQA) will regard the submission of an estimate grade for an externally assessed element as evidence that the course has been completed in that element.

Candidates who have not complied with the assessment requirements in any element (eg due to unauthorised absence from the external examination) will be deemed not to have completed the course in that element. Such candidates **will not receive a grade** for that element and hence **will not receive an overall award** for the subject. In such cases, however, if a grade is gained for any other element, that grade will be recorded on the Certificate.

4 5 Internal Assessment

4 5 1 Introduction

Presenting centres will assess the work of pupils throughout the course for such purposes as class reports and guidance.

For the SQA's purposes, centres will be required to provide for each candidate:

- an estimate of performance for each of Knowledge and Understanding and Problem Solving
- a grade for Practical Abilities.

4 5 2 Estimates of Performance in Knowledge and Understanding and in Problem Solving

Presenting centres will be required to submit to the SQA, by 31 March of the year of the examination, estimate grades for each candidate for Knowledge and Understanding and for Problem Solving. The teacher should determine the estimate grades on the basis of the candidate's work. Estimates may be used by the SQA for its internal procedures, including such cases as absence from external examinations, adverse circumstances and appeal. Evidence in support of these estimates should be retained by centres for submission to the SQA if required.

Informal assessment will normally be undertaken throughout the learning process. It is recommended that teachers assess pupils' achievement at the end of each topic and towards the end of the course. In the latter case, an internal examination similar in structure to the external examination may be used, but each centre will be free to decide the testing procedures which will be used to provide estimates of performance.

4 6 Internal Assessment of Practical Abilities

It is expected that pupils commencing Standard Grade Biology will have a well-established repertoire of basic practical skills. These basic skills have been identified as observing, recording, following instructions, measuring, manipulating and procedural skills.

During the two-year course, pupils should be engaged for a large part of the time in a wide variety of tasks demanding the development of practical abilities. Achievement in this area is a significant outcome of the course and should be recorded in any report on candidate attainment. However, it is important to ensure that any assessment of performance does not adversely affect experimental work.

Teachers should base the grades awarded on evidence of candidates' ability to achieve the course objectives (see 2 3).

Two categories of practical ability are identified, namely:

- Carrying out Techniques
- Designing and Carrying out Investigations.

The assessment of Practical Abilities will focus on these two categories.

4 7 Carrying out Techniques

Techniques fall naturally into two groups, those which relate to fieldwork and those which relate to laboratory work.

The candidate's grade with regard to this ability will be determined by the degree of success achieved in undertaking a total of 10 techniques at varying points throughout the two years of the course. The required techniques for both fieldwork and laboratory work are as follows.

1 Using sampling techniques applicable to ecosystems.
2 Measuring one abiotic factor.
3 Measuring a different abiotic factor.
4 Using a simple biological key for living/preserved specimens.
5 Using a compound microscope with a low power objective lens.
6 Preparing a microscope slide as a wet mount.
7 Making a simple line drawing from a biological specimen.
8 Carrying out a test for starch.
9 Carrying out a test for reducing sugar.
10 Setting up a choice chamber.

One mark should be awarded for successful demonstration of each technique and a record, which subsequently can be scrutinised if necessary for moderation purposes, retained by the centre in respect of each candidate. In addition, it may be necessary to observe candidates carrying out certain techniques. **It is anticipated that, where possible, assessment will occur during ongoing classwork.** It is open to teachers to reassess candidates who have not previously mastered particular techniques.

(Pupil exemplars and associated teacher information describing the requirements for each technique have been issued to all centres by the Scottish Consultative Council on the Curriculum.)

4 8 Designing and Carrying out Investigations

Investigatory experimental work is a fundamental aspect of the course and opportunities to undertake investigations occur in all topics.

Candidates will be required to design methods for carrying out a number of investigations. In normal class activities, it is desirable that candidates collaborate in preparing designs for particular investigations. However, for assessment purposes, candidates must carry out, independently, a minimum of two investigations.

This category is assessed in terms of the extent to which Investigative Skills objectives are achieved by a candidate in the course of carrying out each of his/her two best investigations. During the course, candidates should be given opportunities to undertake a number of investigations, each of which involves demonstration of the thirteen specified Investigative Skills objectives. A list of possible topics is provided in the Appendix.

The Investigative Skills objectives to be assessed are grouped under four headings as follows:

i Generative Skills (G);

ii Experimentation Skills (E);

iii Evaluation Skills (EV);

iv Recording and Reporting Skills (RR).

Two investigations, each covering all of the Investigative Skills objectives should be submitted for the purpose of assessment for certification. At least one of the investigations must involve a continuous variable.

The Investigative Skills objectives to be assessed, together with the related assessment criteria and mark allocations for Standard Grade Biology, are set out in paragraph 4 8 3.

4 8 1 Structure of Investigation

Investigations carried out for certification purposes should provide opportunities for candidates to demonstrate all thirteen of the Investigative Skills objectives. They should be of a suitable standard and should not be repeats of investigations which have already been attempted either during practice or previous assessment.

It is important that a candidate's "report" of an investigation, ie the candidate's written response to an investigation, is structured in a way which allows the teacher and an external moderator readily to identify in the evidence generated those parts which relate to the individual objectives. It is equally important that the degree of structuring provided in an investigation booklet is not so great that the candidate receives an excessive amount of support. The Investigation Booklet issued by the SQA must be used for all investigations conducted for the purposes of assessment for certification.

4 8 2 Conduct of Investigations

The following comments give guidance on the permissible limits of support which may be offered by teachers during an investigation which is assessed for certification purposes.

It is expected that, at the outset of an investigation, teachers will stimulate class or group discussion. Candidates should be introduced to the broad area for investigation by way of a general statement and/or leading questions, perhaps provided on an investigation starter sheet (Appendix I). Discussion should then take place within small groups of candidates; thereafter, individual candidates should decide on a specific area for investigation. In the case of a candidate who suggests a relevant investigatable aspect which cannot be investigated within the constraints of the school situation, the candidate should be directed to other alternatives without penalty. During the generative phase, teachers should advise candidates of any specific problems – eg timing, availability/suitability of apparatus – which may occur with particular investigations.

Subsequent to the discussion, if the candidate is unable to meet the criterion for G1, the teacher should give assistance to enable the candidate to proceed but will not award the mark allocated to this objective. Should a candidate fail to meet a criterion associated with Objective G2, G3 or G4, it is permissible for the teacher to intervene and give sufficient support to enable the candidate to proceed, but the mark allocated **to the relevant criterion** will not be awarded. Where intervention has taken place, a statement to this effect should be made by the teacher at the appropriate point in the candidate's report on the investigation.

After the generative phase (Objectives G1, G2, G3 and G4), candidates must be left to pursue the investigation independently. Teacher intervention in the post-generative phase is permitted only when the candidate fails to adopt standard, safe laboratory practice. In such a case, the mark allocated to the relevant criterion for Objective E1 is forfeited.

Investigations for certification purposes must be carried out and written up by the candidate in class time, with all materials being retained by the teacher between classes.

Candidates should have access neither to their own notes nor to textbooks when carrying out an investigation for the purposes of formal assessment. It should be noted that an investigation booklet is the only support material which may be made available.

4 8 3 Assessment Scheme for Investigation

Assessment of achievement of Investigative Skills objectives is undertaken by applying the following assessment scheme to a candidate's write-up of an investigation. The scheme identifies the criteria which must be satisfied for the purposes of assessment for certification. For each of the criteria, the mark to be awarded where the requirements of the criterion are satisfied is indicated in the table below. Where a criterion is not satisfied, zero marks are awarded. The total mark allocation for each investigation is 24.

For certification purposes, the final mark should be the sum of the scores for the candidate's **two** best investigations to give a score out of 48.

Investigative Skills Objectives and Assessment Criteria

TAPS Investigative Skills Objective The candidate should be able to:		Assessment Criteria and available marks	Marks Total
G1	demonstrate understanding of the problem posed;	Following group discussion, the candidate individually identifies and records an investigable aspect of the problem (1,0)	1
G2	state the aim of the investigation;	Clearly identifies the aim of the investigation in terms of the two relevant variables (1,0)	1
G3	articulate a testable hypothesis;	Articulates a testable hypothesis in terms of the two relevant variables; this should be directional if a continuous variable is chosen (1,0)	1
G4	suggest a broad strategy to adopt;	The strategy gives sufficient detail by description and/or diagram to indicate: *a)* how the chosen independent variable will be altered (1,0) *b)* that the candidate has considered what will have to be measured (1,0)	2
E1	adopt appropriate and safe procedures;	Adopts appropriate and safe procedures (1,0)	1
E2	identify the independent variable to be used and alter it over a suitable range;	*a)* Provides a working definition of the independent variable (1,0) *b)* Alters the independent variable over an appropriate range taking account of a suitable number of types or values (1,0)	2
E3	control all relevant variables as necessary;	*a)* Makes a written statement of the variables which need to be actively controlled by the candidate (1,0) *b)* Controls these variables in practice (1,0)	2
E4	make valid, reliable measurement of the dependent variable;	*a)* Uses a valid method of measuring the dependent variable (1,0) *b)* Evidence is provided of a form of repeat/replicate testing which improves the reliability of the results **or** a valid written justification is given for not repeating/ replicating measurements (1,0)	2
RR1	tabulate results with appropriate headings and units of measurement;	*a)* Values (or types) with appropriate headings for independent, dependent (and any derived) variable are entered in the table (1,0) *b)* Appropriate units or their correct abbreviations are entered in the table (1,0)	2

Investigative Skills Objectives and Assessment Criteria *(continued)*

TAPS Investigative Skills Objective The candidate should be able to:	Assessment Criteria and available marks	Marks Total
RR2 present the results on a graph or chart;	*a)* A graph or chart of a suitable size and scale is produced (1,0) *b)* Both axes have appropriate labels and units (1,0) *c)* Plots all the points/bars accurately (1,0) *d)* Draws line/curve of best fit or joins up the points as appropriate when the independent variable is continuous **or** draws a bar chart when independent variable is not continuous (1,0)	4
Ev1 draw a valid conclusion inter-relating the appropriate variables;	Draws a conclusion which inter-relates the appropriate variables or states that no firm conclusion can be drawn (1,0)	1
Ev2 use results to evaluate the original hypothesis;	Confirms hypothesis if appropriate **or** refutes hypothesis and replaces it with appropriate substitute **or** states that no conclusion can be drawn (1,0)	1
RR3 describe how the investigation was carried out.	The description includes: *a)* a labelled diagram and/or statement of the apparatus used; (1,0) *b)* an account of the procedure adopted to measure the dependent variable; (1,0) *c)* an account of how the independent variable was altered; (1,0) *d)* an indication of how variables which were the investigators' responsibility to control were kept constant (1,0)	4

4 9 Recording of Assessment of Practical Abilities

For each candidate, a summary record should be kept of the outcome of the assessment of the two categories of Practical Abilities, Carrying out Techniques and Designing and Carrying out Investigations.

For Carrying out Techniques, a record should be kept of the mark (1 or 0) achieved for each of the ten techniques and, thereafter, the total of these marks.

4 9 *(continued)*

For Designing and Carrying out Investigations, the total mark obtained for each Investigation should be recorded, together with the sum of these two marks. Form Ex5 (Flyleaf) will be issued annually to presenting centres for use in connection with the submission of materials at the moderation stage. The reverse side should be used to record the above details of a candidate's performance in Practical Abilities. Presenting centres will also be provided on an annual basis with details of the arrangements for the submission of internal assessments of Practical Abilities for all candidates.

4 10 Evidence of Attainment of Practical Abilities

Evidence of a candidate's attainment of Practical Abilities should comprise a summary report on the Ex5 (Flyleaf), as described in paragraph 4 9 above, together with the reports on the two best investigations.

Where a centre elects to assess Carrying out Techniques by using the exemplar materials prepared by the Central Support Group for Biology and issued by the Scottish Consultative Council on the Curriculum in 1988, the exemplar materials should not be submitted as evidence to support internal grades awarded. Where a centre decides to modify the CSG exemplar materials for all or any of the ten required techniques, or where alternative approaches are used, **one** complete set of all teacher and pupil assessment materials should be retained for possible submission to the SQA along with the evidence in support of the internal grades awarded.

For Designing and Carrying out Investigations, the evidence should be in the form of an investigation booklet for each of the two investigations. Each of these investigation booklets must give a clear indication of the mark awarded for each of the Investigative Skills objectives and also of the total mark awarded.

4 11 Grade for Practical Abilities

For each candidate, **a total score for Practical Abilities should be determined by multiplying the mark awarded for Carrying out Techniques by 2 and adding it to the mark awarded for Designing and Carrying Out Investigations**. The grade for the element should then be determined by reference to the following table.

Marks range	Grade
58-68	1
49-57	2
39-48	3
29-38	4
19-28	5

Candidates for whom there is evidence in support of at least one technique or investigation and who achieve an overall total score of less than 19 marks should be awarded a Grade 7 for Practical Abilities.

4 12 Moderation of Internal Assessments

To ensure the uniform application of the Extended Grade Related Criteria for Practical Abilities, each year a sample of presenting centres will be required to submit to the SQA evidence in support of internal assessments of Practical Abilities for a sample of candidates. Where a centre's internal assessments cannot be confirmed, the centre will be required to carry out re-assessment as necessary.

Section 5

Grade Related Criteria

5 Grade Related Criteria

5 1 Definition

Grade Related Criteria (GRC) are positive descriptions of performance against which a candidate's achievement is measured. Direct comparisons are not made between the performance of one candidate and that of another.

5 2 Application of GRC

For each element, GRC are defined at two Levels of performance: General and Credit. Two grades are distinguished at each Level, Grades 4 and 3 at General Level and Grades 2 and 1 at Credit.

Grade 5 is available for candidates who narrowly fail to reach the standard of performance required for Grade 4. Grade 7 will be awarded to candidates who have completed the course but have not fulfilled the requirements of Grade 5 or better. Grade 6 will not be available for an element.

5 3 Types of GRC

Summary GRC are broad description of performance. They are published as an aid to the interpretation of the profile of attainment by candidates, parents, employers and other users of the Certificate.

Extended GRC are more detailed descriptions of performance. They are intended to assist teachers in making their assessments for each element, and to be used by examiners when conducting external assessment.

5 4 Knowledge and Understanding – Summary GRC

General Level (Grades 4, 3)

The candidate has demonstrated knowledge and understanding of biological facts, ideas and terminology and of some related applications of biology in society.

Credit Level (Grades 2, 1)

The candidate has demonstrated knowledge and understanding of complex biological facts, ideas and terminology and of related applications of biology in society.

5 5 Problem Solving – Summary GRC

General Level (Grades 4, 3)

The candidate has demonstrated ability to extract, collate and interpret information from a variety of familiar sources, to present information in an acceptable form, to carry out simple calculations, and, in respect of experimental procedures, to comment on the validity of procedures, to suggest possible improvements and to draw conclusions, explain results and make predictions with some guidance.

Credit Level (Grades 2, 1)

The candidate has demonstrated ability to extract, collate and interpret information accurately from a wide variety of sources, to present information in the most appropriate form, to carry out calculations, and, in respect of experimental procedures, to comment with supporting argument on the validity of procedures, to suggest possible improvements and sources of error, and to draw conclusions, explain results and make predictions.

5 6 Practical Abilities – Summary GRC

General Level (Grades 4, 3)

The candidate has demonstrated ability to carry out a range of biological techniques, and to design and carry out investigations with a degree of competence.

Credit Level (Grades 2, 1)

The candidate has demonstrated ability to carry out a wide range of biological techniques and to design and carry out investigations with a high degree of competence.

5 7 Descriptions of Grades

These describe performance within Levels. They apply to all elements.

Grade 5 Judged by the criteria for General Level, the candidate has demonstrated a significant but not satisfactory overall standard of performance.

Grade 4 The candidate has met the criteria for General Level, demonstrating a satisfactory overall standard of performance.

Grade 3 The candidate has met the criteria for General Level, demonstrating a high overall standard of performance.

Grade 2 The candidate has met the criteria for Credit Level, demonstrating a satisfactory overall standard of performance.

Grade 1 The candidate has met the criteria for Credit Level, demonstrating a high overall standard of performance.

5 8 Knowledge and Understanding – Extended GRC

General Level (Grades 4, 3)	Credit Level (Grades 2, 1)
The candidate can demonstrate achievement of a majority of the General Level Learning Outcomes as listed in the topic descriptions.	The candidate can demonstrate achievement of a majority of the Credit Level Learning Outcomes as illustrated in the topic descriptions.

Descriptions of grades are given in **5 7**.

5 9 Problem Solving – Extended GRC

	General Level (Grades 4, 3)	Credit Level (Grades 2, 1)
Candidates should be able to demonstrate their abilities in problem solving by:	The candidate can:	The candidate can:
a) handling and processing information *b)* evaluating procedures and information, drawing conclusions and making predictions.	• select relevant information from texts, tables, charts, keys, graphs and diagrams which use terms and ideas appropriate to General Level • present information in a variety of forms, including written summaries, tables, bar and line graphs, histograms and simple branched keys • carry out whole number calculations to find percentages, averages and ratios • comment on the validity of a suggested experimental procedure or procedures and suggest improvements • from information obtained appropriate to General Level, draw a valid conclusion • from given information appropriate to General Level, make a valid prediction.	• select relevant information from texts, tables, charts, keys, graphs and diagrams which use terms and ideas appropriate to Credit Level • present information in a variety of forms, including extended writing, tables, appropriate graphical representations of complex relationships and paired-statement keys • carry out more complex calculations to find percentages, averages and ratios; • comment with supporting argument on the validity of a suggested experimental procedure or procedures with regard to limitations of equipment, sources of error and possible improvements • from information obtained appropriate to Credit Level, draw a valid conclusion and provide some justification • from given information appropriate to Credit Level, make a valid predication.

Descriptions of grades are given in **5 7**.

5 10 Practical Abilities – Extended GRC

The candidate should be able to demonstrate the following abilities:	General Level (Grades 4, 3) The candidate can:	Credit Level (Grades 2, 1) The candidate can:
a) Carrying out Techniques.	• carry out some of the prescribed techniques	• carry out a high proportion of the prescribed techniques
b) Designing and Carrying out Investigations.	• demonstrate competence in a proportion of investigative skills objectives.	• demonstrate competence in a high proportion of investigative skills objectives.

Descriptions of grades are given in **5 7**.

Appendices

Possible Investigation Topics

GERMINATING SEEDS

THE WORLD OF PLANTS SUB-TOPIC b

If seeds are to germinate they must have suitable conditions. Seed packets usually give a lot of information about the best conditions for planting seeds.

What might affect how quickly seeds will germinate?

SEEDLING GROWTH

THE WORLD OF PLANTS SUB-TOPIC b

Some people are said to have 'green fingers' because they seem to be able to grow plants from seed so well. There is really nothing mysterious about such people, they simply provide plants with the required conditions.

What factors might affect the growth of young seedlings?

BURSTING PLANT CELLS

INVESTIGATING CELLS
SUB-TOPIC b

In certain circumstances beetroot cells rupture when placed in liquids and as a result the red colour can leak out of the cells into the surrounding liquid.

What might affect the number of cells damaged when a piece of beetroot is placed in a liquid?

CATALASE

INVESTIGATING CELLS
SUB-TOPIC b

All living cells contain the enzyme catalase which can break down hydrogen peroxide into oxygen and water. You can study the reaction in a test tube using pieces of tissue.

What might affect how quickly oxygen is produced when pieces of tissue are placed in hydrogen peroxide solution?

DIGESTIVE ENZYMES

INVESTIGATING CELLS
SUB-TOPIC d

There are many digestive enzymes in your gut.
These enzymes break down the different foods you eat. Trypsin, for instance, breaks down protein.

What factors might affect how well Trypsin breaks down protein?

MICROORGANISM GROWTH

BIOTECHNOLOGY SUB-TOPIC b

Many microorganisms grow on our food and spoil it. You must have seen mould growing on bread. Many factors affect the rate at which microorganisms will grow on food.

What factors might affect the rate at which microorganisms will grow on bread?

BIOLOGICAL WASHING POWDERS

BIOTECHNOLOGY SUB-TOPIC c

There is a wide variety of different brands of washing powders on the market. Some of these are called 'biological' washing powders because they contain enzymes.

What factors might affect the activity of biological washing powders?

Appendix II

(append to Arrangements issued August 1997)

Assessment of Practical Abilities

Standard Grade Biology, Chemistry, Physics and Science

In August 1997 SQA issued revised arrangements for the assessment of Practical Abilities in all of the science subjects specified above. These revised arrangements were implemented for the first time in 1999.

Following central moderation of the internal assessment of these subjects, SQA has decided that the following additional guidance should be provided to centres. **This additional guidance does not change any requirements of the published Arrangements documents and should be read in conjunction with these documents.**

General Comments

1 The assessment of candidate performance is carried out with reference to the Extended Grade Related Criteria (EGRC) that are included in Arrangements documents. Across the science subjects, the EGRC for Practical Abilities at Foundation, General and Credit Levels detail requirements for *both* techniques and investigations. In addition, the Summary GRC for Practical Abilities confirm that both techniques *and* investigations are required at all levels.

To be awarded any grade other than 7 in Practical Abilities, candidate evidence must be consistent with the EGRC and so must cover **both techniques and investigations**. For example, to be awarded any grade between 1 and 6 for Practical Abilities in Standard Grade Science, in achieving the minimum mark specified in the Arrangements document, candidates must:

- carry out at least one practical technique
  and
- achieve at least one Investigative Skill objective.

All of the Arrangements documents for science Standard Grades include statements of the type:

> "Candidates for whom there is evidence in support of at least one technique or investigation and who achieve an overall total of less than X marks should be awarded a Grade 7 for Practical Abilities."

These statements apply only to the award of Grade 7. A small number of schools have inferred, incorrectly, that these statements also apply to the award of grades other than 7. As indicated above, this inference is consistent neither with the EGRC nor the Summary GRC.

A candidate who attempts neither techniques nor investigations will be deemed not to have completed the course in the Practical Abilities element. Such a candidate will not receive a grade for this element and hence will not receive an overall grade for the subject.

2 **To comply with the EGRC**, investigations undertaken by candidates **must** be relevant to the subject eg investigation of:

- the period of a pendulum is inappropriate for Chemistry or Biology candidates
- lathering is inappropriate for Physics candidates.

Science candidates may undertake an investigation in any science subject. All candidates should have a clear understanding of the science content of their investigations.

3 Investigations carried out for certification purposes **must** provide opportunities for candidates to demonstrate **all** of the thirteen skills objectives. During the generative phase it is in order for the teacher to direct candidates away from trivial or other investigations that will not permit candidates to demonstrate particular skills. For example a candidate might want to investigate the rate of reaction of copper with dilute acids. This would result in a graph where all of the points would be on one of the axes. This investigation is not appropriate for certification purposes as it would not permit the candidate to demonstrate skills in relation to criteria *a*, *c* and *d* of objective *RR2*. The candidate should be directed to alternatives **without penalty**.

4 The booklets supplied by SQA must be used. No change is permitted to the text of the booklets, or to the sequence. The following modifications **are permitted**:

- addition of school or class details to the front page
- reproduction in A4 or other format
- alteration of font size
- highlighting the boxes for marks awarded by direct observation
- photocopying graph paper into the booklet.

5 To facilitate assessment and moderation, candidates should provide evidence in the appropriate places in the Investigation Booklet. For example, evidence relevant to criterion *G1* should normally be written in the space following instruction number 1. Where marks are awarded for evidence written elsewhere in the booklet, this must be clearly recorded by the assessor.

6 Candidates should be encouraged to avoid the use of the term 'amount' where other terms, eg mass, volume, weight, are more appropriate. Use of 'amount' usually results in loss of marks, as responses are misleading and/or ambiguous.

7 At least one investigation must have a continuous independent variable to ensure that all candidates have the opportunity to draw a line graph.

8 To aid moderation, the teacher should indicate briefly in the booklet why a candidate has not been awarded marks for one or more of the criteria *G1*, *G2*, *G3* or *G4*. Similarly, the teacher should indicate briefly why marks dependent on direct observation (criteria *E1*, *E3b* and *E4a*) have not been awarded.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
G1	demonstrate understanding of the problem posed;	Following group discussion, the candidate individually identifies and records an investigable aspect of the problem.	1 Having thought about the problem and talked about it with others in your class, write down the factor which you are going to investigate.	Where the dependent variable is given, the candidate must give an independent variable that is to be investigated. Where neither variable is given, the candidate could give **either** an independent or a dependent variable eg: • concentration of acid or rate of reaction • light intensity or number of seeds germinating • length of pendulum or period. A list of variables is not required. Candidates who make a list must indicate the variable they have chosen to investigate. If the candidate is *unable to meet this criterion*, the teacher should give assistance to enable the candidate to proceed but should *not award the mark* allocated to this objective. In the case of a candidate who identifies a relevant investigable aspect *that cannot be investigated within the constraints of the school situation* the candidate should be directed to alternatives **without penalty**. **Note:** The term 'constraints of the school situation' applies to any circumstance that would prevent the candidate from completing the investigation eg necessary equipment is not available, equipment that is available is insufficiently sensitive, length of school period is too short etc…

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
G2	state the aim of the investigation;	Clearly identifies the aim of the investigation in terms of the two relevant variables.	2 What is the aim of your investigation?	**Both** the independent and dependent variables must be mentioned eg to find out how: • *light intensity* affects the *germination* of seeds • the *length* of pendulum affects the *period* • the *concentration* of an acid affects *rate of reaction.* Candidates can use their own words – ie they do not have to use precise scientific terms to meet this criterion.
G3	articulate a testable hypothesis;	Articulates a testable hypothesis in terms of the two relevant variables; this should be directional if a continuous variable is chosen.	3 What is your hypothesis? (What do you expect to happen?)	Where a discontinuous variable is used, candidates should not be penalised for using the word 'change' eg the following are acceptable: • I expect voltage to change when I use electrodes made of different metals. • I expect height of rebound to change when I use different surfaces. When a continuous variable is used the direction of change **must** be mentioned eg I expect: • *more* seeds to germinate as temperature rises • current to *increase* as voltage increases. If the candidate is *unable to meet this criterion*, the teacher should give assistance to enable the candidate to proceed but should *not award the mark* allocated to this objective.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
G4	suggest a broad strategy to adopt;	The strategy gives sufficient detail by description and/or diagram to indicate:	4 Describe briefly how you are going to carry out your investigation.	
		a) how the chosen independent variable will be altered.		*a)* It is not sufficient for candidates to say what they are going to change; they **must** state how they are going to effect the change eg I will change: • the voltage … by adding more batteries/by turning the voltage control on the power supply. ('by using a power supply' on its own is insufficient as many common power supplies have a single output voltage) • the temperature … by heating with a bunsen burner/water bath • light intensity … by putting one seed tray in a cupboard, one beside a window and one in a shaded part of the room. In each case the text after the ellipsis is essential. For investigations where candidates are provided with prepared samples of the independent variable (eg acids of different concentrations), they should indicate that they are using a different sample for each test.
		b) that the candidate has considered what will have to be measured.		*b)* Candidates do not require to state how they intend to measure the dependent variable. It is sufficient for candidates to state that they intend to measure it eg I will: • measure the volume of gas given off • measure the current • count the number of seeds that germinate. Where the independent variable requires to be measured, candidates should also state that they intend to measure this variable.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
E1	adopt appropriate and safe procedures;	*Adopts appropriate and safe procedures. (Mark awarded by teacher observation)*	7 You should now carry out your investigation in a safe way.	**Both** appropriateness and safety are essential. Thus the mark allocated to this objective should not be awarded if the procedures followed by candidates: • do not allow successful completion of the investigation eg inappropriate method of measuring either variable • put themselves or anyone else at risk.
E2	identify the independent variable to be used and alter it over a suitable range;	*a)* Provides a working definition of the independent variable. *b)* Alters the independent variable over an appropriate range taking account of a suitable number of types or values.	5 State clearly what you are going to change. 8 Make a table of your results.	*a)* The candidate must refer to the **independent** variable. *b)* The minimum number of types of values must be **appropriate to the investigation.** While a minimum of three values will be appropriate in many investigations, this number would be insufficient for others. For example, the three pairs of values below could be obtained by candidates investigating *either* the variation of range with angle of projection (smooth curve with maximum at 45°) *or* variation of current with voltage (straight line through the origin for ohmic circuit). *Variable 1* 10 20 30 *Variable 2* 3.2 6.4 8.8 These three points on their own are insufficient to establish the relationship between these variables.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
E3	control all the relevant variables as necessary;	*a)* Makes a written statement of the variables which need to be actively controlled by the candidate. *b)* *Controls these variables in practice.*	6 What variables are you going to keep the same?	*a)* The statement should include all variables that **must** be controlled by the candidate to ensure that the results of the investigation are valid. For example, if maintaining a constant temperature is crucial to the investigation, temperature must be included in the statement. However, if small variations in laboratory temperature do not have a significant effect on the measurements made, the candidate need not include temperature in the list. A candidate who omits any variable that must be controlled should not be awarded this mark. *b)* Candidates must **actively** control all of the variables included in their lists.
E4	make valid, reliable measurement of the dependent variable;	*a)* *Uses a valid method of measuring the dependent variable.*	7 You should now carry out your investigation in a safe way. Use the space below to note results or for rough notes.	*a)* Candidates must use a valid method to measure the dependent variable. (The method used by the candidate to measure the independent variable is irrelevant to this criterion. However, a candidate using an invalid method for measuring the independent variable would not be awarded the mark allocated to objective *E1*.)

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
E4 *(cont)*		*b)* Evidence is provided of a form of repeat/ replicate testing which improves the reliability of the results **or** a valid written justification is given for not repeating/ replicating measurements.	8 Make a table of your results.	*b)* In addition to taking more than one reading of the same measurement, repetition/replication may involve: • simultaneous experiments eg planting many seeds at the same time • measuring multiples eg the time for 10 swings of a pendulum. Pooling of results is not permitted. The purpose of replication is to **improve the reliability** of the results. Thus a candidate who calculates an average incorrectly should not be awarded the mark allocated to this criterion. Normal constraints of the school situation, eg insufficient apparatus, cost, length of period etc. are **not** valid justifications for repeat/replicate testing not being carried out. Candidates should have been directed to other investigable aspects without penalty (see comments for objective *G1*).
RR1	tabulate results with appropriate headings and units of measurement;	*a)* Values (or types) with appropriate headings for inde-pendent, dependent (and any derived) variable are entered in the table. *b)* Appropriate units or their correct abbreviations are entered in the table.	8 Make a table of your results.	*a)* Data must be presented in clearly discernible rows and columns. Headings should be clear and appropriate. Candidates should be encouraged to use a ruler when drawing tables. However, candidates should not be penalised for omitting table lines. Data errors, should be penalised, eg where it is apparent that the candidate has recorded incorrect readings for either variable. *b)* Units are required for **both** the independent and dependent variables. The units may appear in the table headings or in the body of the table. Where a table includes repeated measurements and an average value the units do not need to be repeated for each heading or entry eg: *Reading 1* *Reading 2* *Reading 3* *Average reading (units)* would be acceptable for one variable.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
RR2	present the results on a graph or chart;		9 On square ruled paper or graph paper draw a graph or a chart based on your results. Staple the square ruled paper or graph paper to your booklet.	During the generative phase it is in order for the teacher to direct candidates away from investigations that will not permit the candidates to demonstrate these skills (see general comment 3 on page 77).
		a) A graph or chart of suitable size and scale is produced.		*a)* The decision about *suitability* of size of a graph should relate to the quality of the communication, ie does the graph communicate findings clearly? A graph that is difficult to read or interpret does not meet this criterion. Numerical scales must rise in equal increments (eg 0, 2, 4, 6, 8 ... **not** 0, 2, 5, 11, 23 ...).
		b) Both axes have appropriate labels and units.		*b)* Any error in labelling or units should be penalised *unless* the candidate has already been penalised for the error under criterion *RR1a* or *RR1b*. Line graph scales do not need to begin at zero. However, candidates using such scales will have to exercise great care when drawing conclusions. For bar charts, the y-axis should begin at zero.
		c) Plots all the points/bars accurately.		*c)* Plotting either average values or all replicates is acceptable. The points plotted should be consistent with the data in the table produced by the candidate. Incorrect data (penalised under criterion *RR1a*) plotted correctly should not be penalised again here.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
RR2 *(cont)*		*d)* Draws line/curve of best fit or joins up the points as appropriate when the independent variable is continuous **or** draws a bar chart when independent variable is not continuous.		*d)* A line/curve of best fit must be drawn where this is appropriate eg in physics investigations. Joining of points with a series of straight lines should be accepted only if this is appropriate to the investigation. Inappropriate extrapolation should be penalised eg straight line extended well beyond highest/lowest values without supporting data. Vertical solid lines (spikes) should be penalised in line graphs. In a bar chart adjacent bars may be separate or touching. Candidates should be encouraged to use bars of equal width and to avoid using spikes.
Ev1	draw a valid conclusion inter-relating the appropriate variables;	Draws a conclusion which inter-relates the appropriate variables or states that no firm conclusion can be drawn.	10 What conclusion can you draw from your results?	The conclusion should relate to the aim of the investigation (*G2*) and should reflect the findings. It should be more than a simple restatement of the results. acceptable: "The higher the temperature the more seeds germinated." not acceptable: "Half the seeds germinated at 5°C and all the seeds germinated at 25°C." Where a valid conclusion can be made that is directional, the direction of change must be included in the candidate's conclusion. acceptable: "The longer the pendulum string the greater the period." unacceptable: "The period of the pendulum changes as the string gets longer." Candidates do not have to use precise scientific terms to meet this criterion ie candidates may answer in their own words.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
Ev2	use results to evaluate the original hypothesis;	Confirms the hypothesis if appropriate **or** refutes hypothesis and replaces it with appropriate substitute **or** states that no conclusion can be drawn.	11 What can you say about your hypothesis? (Circle A or B or C below. If your circle B complete the sentence.) A My hypothesis in part 3 is correct. B My hypothesis in part 3 should be changed to … C My results do not allow me to choose A or B.	If the candidate is unable to meet the criterion for skill objective *G3*, the teacher should give assistance so that the candidate has an opportunity to gain the mark for objective *Ev2*. Where this is the case the teacher should record an appropriate comment on page 2 in the candidate's investigation booklet.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
RR3	describe how the investigation was carried out.	The description includes: *a)* a labelled diagram and/or statement of the apparatus used; *b)* an account of the procedure adopted to measure the dependent variable; *c)* an account of how the independent variable was altered; *d)* an indication of how variables which were the investigator's responsibility to control were kept constant.	12 Describe clearly how you set up and carried out your investigation.	*a)* Key apparatus must appear in the text or in a labelled diagram. A list of apparatus is not required. *b)* This account should describe the procedure actually used by the candidate. *c)* This account should describe the procedure actually used by the candidate. The procedure used may be different from the procedure indicated for objective *G4* eg a candidate may have planned to change temperature using a bunsen burner but may actually have used an immersion heater. *d)* Candidates should indicate how they controlled **all** of the variables specified in their statement for criterion *E3a*. Some of the information required may be communicated by a clearly labelled diagram eg diagram could show that temperature was controlled by immersion of apparatus in crushed ice.