Science Education Key Learning Area

Biology Curriculum and Assessment Guide (Advanced Level)

Jointly prepared by
The Curriculum Development Council and the Hong Kong Examinations Authority

Recommended for use in schools by the Education Department HKSAR
(2002)

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PREAMBLE

This Curriculum and Assessment Guide is one of the series jointly prepared by the Hong Kong Curriculum Development Council (CDC) and the Hong Kong Examinations Authority (HKEA). It forms the basis for learning and teaching of the subject curriculum as well as for setting public assessments. The issue of this one single document on curriculum and assessment guide aims at conveying a clear message to the public that public assessments are an integral part of the school curriculum and promoting the culture of "assessment for learning" to improve learning and teaching.

The CDC is an advisory body giving recommendations to the Hong Kong Special Administrative Region Government on all matters relating to curriculum development for the school system from kindergarten to sixth form. Its membership includes heads of schools, practising teachers, parents, employers, academics from tertiary institutions, professionals from related fields or related bodies, representatives from the HKEA and the Vocational Training Council, as well as officers from the Education Department.

The HKEA is an independent statutory body responsible for the conduct of the Hong Kong Certificate of Education Examination and the Hong Kong Advanced Level Examination. The governing council of the HKEA includes members who are mainly drawn from the school sector, tertiary institutions, government bodies, professionals and persons experienced in commerce and industry.

This Curriculum and Assessment Guide is recommended by the Education Department for use in secondary schools. The subject curriculum developed leads to appropriate examinations provided by the HKEA. In this connection, the HKEA has issued a Handbook as a supplement to provide information on the format of the public examinations of the various subject curricula (such as the proportion of multiple-choice questions and open questions) and the related rules and regulations.

Both the CDC and HKEA will keep the subject curriculum under constant review and evaluation in the light of classroom experiences and students' performance in the public assessments respectively. All comments and suggestions on the Curriculum and Assessment Guide may be sent to:

Chief Curriculum Development Officer (Science)
Education Department
4/F, 24 Tin Kwong Road
Kowloon
Hong Kong

I. AIMS AND OBJECTIVES

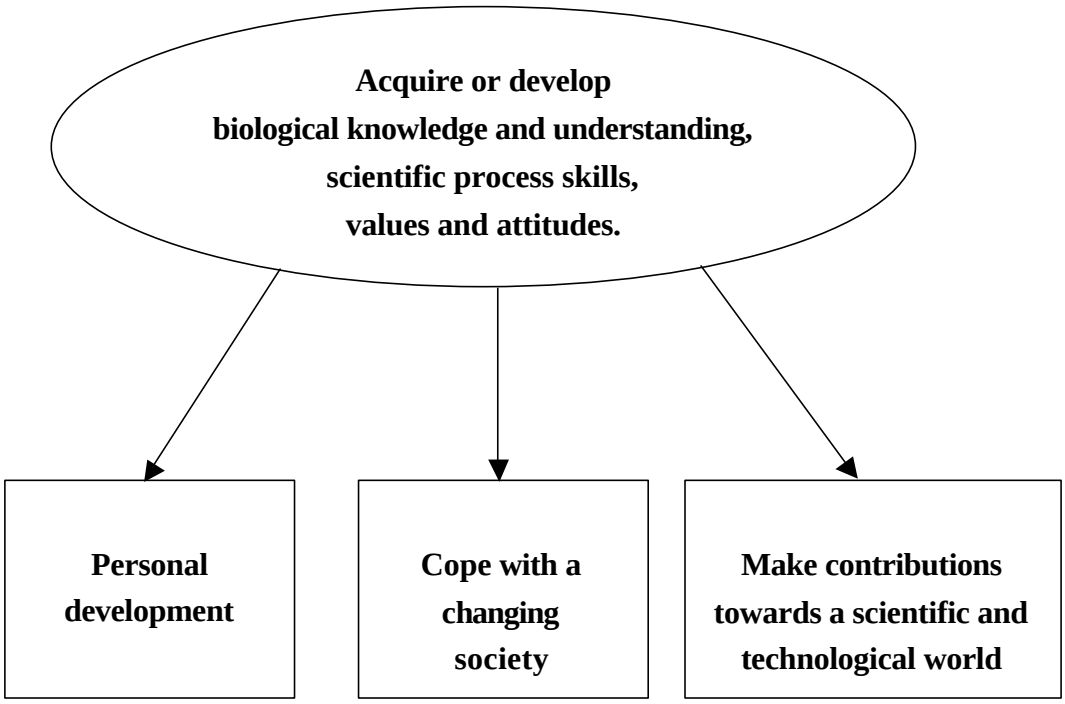
Aims

The A-Level Biology Curriculum aims to provide learning experiences through which students will acquire or develop the necessary biological knowledge and understanding, scientific process skills, values and attitudes, for their personal development, for coping with a dynamically changing society and for contributing towards a scientific and technological world.

1. For their **personal development**, students will be able to
   - 1.1 observe objectively and critically;
   - 1.2 enquire, think and reason scientifically and creatively;
   - 1.3 solve problems through informed judgements and decisions;
   - 1.4 be acquainted with the language of science and be equipped with the skills in communicating ideas in biology-related contexts; and
   - 1.5 apply biological knowledge and understanding to develop positive values and attitudes towards a healthy lifestyle.

2. For **coping with a changing society**, students will be able to
   - 2.1 relate and apply biological knowledge and understanding to everyday life and to the needs of a changing society;
   - 2.2 develop and sustain an attitude of curiosity to investigate and explore; and
   - 2.3 develop an interest in, and enjoyment of, the study of the living world so as to prepare themselves to become life-long learners in the related fields of science and technology.

3. For **contributing towards a scientific and technological world**, students will be able to
   - 3.1 develop an awareness of the relationships between organisms and their environment, and the effect of human activities on these relationships;
   - 3.2 deepen their respect for all forms of life and their respective habitats ;
   - 3.3 develop an attitude of contributory responsibility, including a strong sense of commitment to conserve, protect and maintain the quality of all environments for future generations; and
   - 3.4 develop an earnest concern for biological issues in personal, social, economic, environmental and technological contexts.



Objectives

The general objectives listed below are to be achieved through the course of study of biology at A-Level as a whole. The objectives are categorised into three domains: knowledge and understanding, scientific process skills, and values and attitudes. Throughout the course of studying the biology curriculum, students will acquire the necessary knowledge, skills and attitudes under various biology-related contexts. Specific learning objectives will be highlighted in the section.

A. Knowledge and Understanding

Students will acquire **knowledge** and develop **understanding** of:

1. the nature of biology;
2. biological terms, biological facts, biological concepts and principles;
3. biological practical techniques;
4. the applications and uses of biology in everyday life;
5. the implications of biology for society and the environment;
6. current issues and developments in biology; and
7. the historical development of biological concepts.

B. Scientific Process Skills

Students will acquire or develop the following skills so that they can study biological phenomena through the scientific process:

1. developing scientific thinking and problem-solving skills;
2. recognising biological problems; such problems are often characterised by the presence of a range of interacting variables;
3. planning and performing investigations; formulating working hypotheses and devising tests for them, using controls where appropriate;
4. searching, collecting and organising information from various sources; communicating and presenting them in a clear and logical form; and evaluating and applying them to solve problems in familiar and unfamiliar situations;
5. analysing and interpreting data, and extrapolating from them;
6. observing and describing objects and phenomena accurately;
7. interpreting drawings and photographs of biological structures;
8. formulating generalisations in the light of both first-hand and second-hand evidence;
9. using instruments and apparatus to the limits of accuracy appropriate to a given problem; and
10. performing common laboratory techniques and handling chemicals, instruments, apparatus and biological materials carefully and safely.

C. Values and Attitudes

Students will develop the following **values and attitudes**:

1. an interest and enjoyment in studying living organisms and their interrelationships;
2. a responsible regard for both the living and non-living components of the environment;
3. ethical behaviour;
4. a critical and inquiring mind;
5. an objective attitude towards evidence;
6. a positive attitude in discussing biological issues in personal, social, economical, environmental and technological contexts;
7. an awareness that the body of biological knowledge is not static; and that experimental and investigatory work are important for its advancement;
8. an awareness of the need for appropriate safety procedures;

9. an awareness of both the usefulness and limitations of hypotheses in making predictions and explaining biological phenomena; and
10. a desire for critical evaluation of the consequences of the applications of science and recognising their responsibilities to conserve, protect and maintain the quality of all environments for future generations.

II. CURRICULUM FRAMEWORK

A. Organisation

This curriculum serves as a continuation of the CDC Biology Curriculum for S4-5. With careful consideration of students' prior knowledge and everyday experiences, it is designed to cover major aspects of biology, along with its social and technological relationships.

There are thirteen sections in this biology curriculum. Each of Sections 1 – 12 consists of two major parts: an ***Overview*** and a table of contents which is organised into three columns: ***Learning objectives, Possible learning and teaching activities,*** and ***Expected learning outcomes.*** Section 13 provides the suggestions on the treatment of practical works.

(a) The overview

This part introduces the main theme and foci of each section. It suggests the overarching expected learning outcomes of the section. It also tries to make plain any major relationships with the other topics of this Biology Curriculum so that different sections can be studied with proper integration.

(b) The table of contents

(1) ***Learning objectives*** – this column lists out the areas in biology that students are expected to learn. Through these learning areas students may acquire or develop the skills and attitudes which are listed on page 3. These learning objectives provide a basic framework upon which the learning experiences and teaching activities can be developed.

(2) ***Possible learning and teaching activities*** – this column suggests activities that can be done by either the students or the teachers to enable students to achieve the learning objectives. The list includes a wide range of activities, such as questioning, discussions, debates, practical works, investigations, information searching and project works, etc. The duration for each activity varies, and teachers should allow sufficient time for students to develop the specific skills. Teachers should exercise their professional judgement in selecting some of the suggested activities or other relevant activities to enhance biology learning in suitable contexts, and to meet the interest and abilities of their students.

(3) ***Expected learning outcomes*** – this column lists out a range of learning outcomes, with different levels of abilities, which can be demonstrated by students in relation to the learning objectives. In most cases, only the learning outcomes with the highest cognitive ability (e.g. review, evaluate, relate, etc.) are listed. It is expected that students can also demonstrate other learning outcomes with lower cognitive abilities (e.g. state, point out, outline, etc.). Students can use these outcomes as the basis for self-assessment. Teachers can also use these outcomes to set assessment activities for checking the progress of learning and teaching.

Together with the ***Overview*** and the ***Learning objectives*** listed in the first column, the ***Expected Learning Outcomes*** listed in the third column form the basis for the public examination. For the examination requirement of practical skills and abilities, teachers and students should refer to Section 13 in the curriculum framework and the Handbook for A-Level Biology Teacher Assessment Scheme issued by the Hong Kong Examinations Authority for details. The sequence of presentation of topics in this guide ***should not be regarded as a fixed teaching order***. Individual topics should be studied as integral parts of the whole curriculum, and not as separate entities. The biological structures and processes, for example, should be considered and understood in the context of the whole organism where appropriate and not in isolation.

B. Time Allocation

The A-Level Biology Curriculum is divided into thirteen sections. With a time allocation of eight 40-minute periods each week, a total of 362 periods in Secondary 6 and 7 should be enough to cover the whole curriculum, including practical work. An estimate of the number of periods required for each section is shown below to provide some guidance on the weighting to be placed on individual sections.

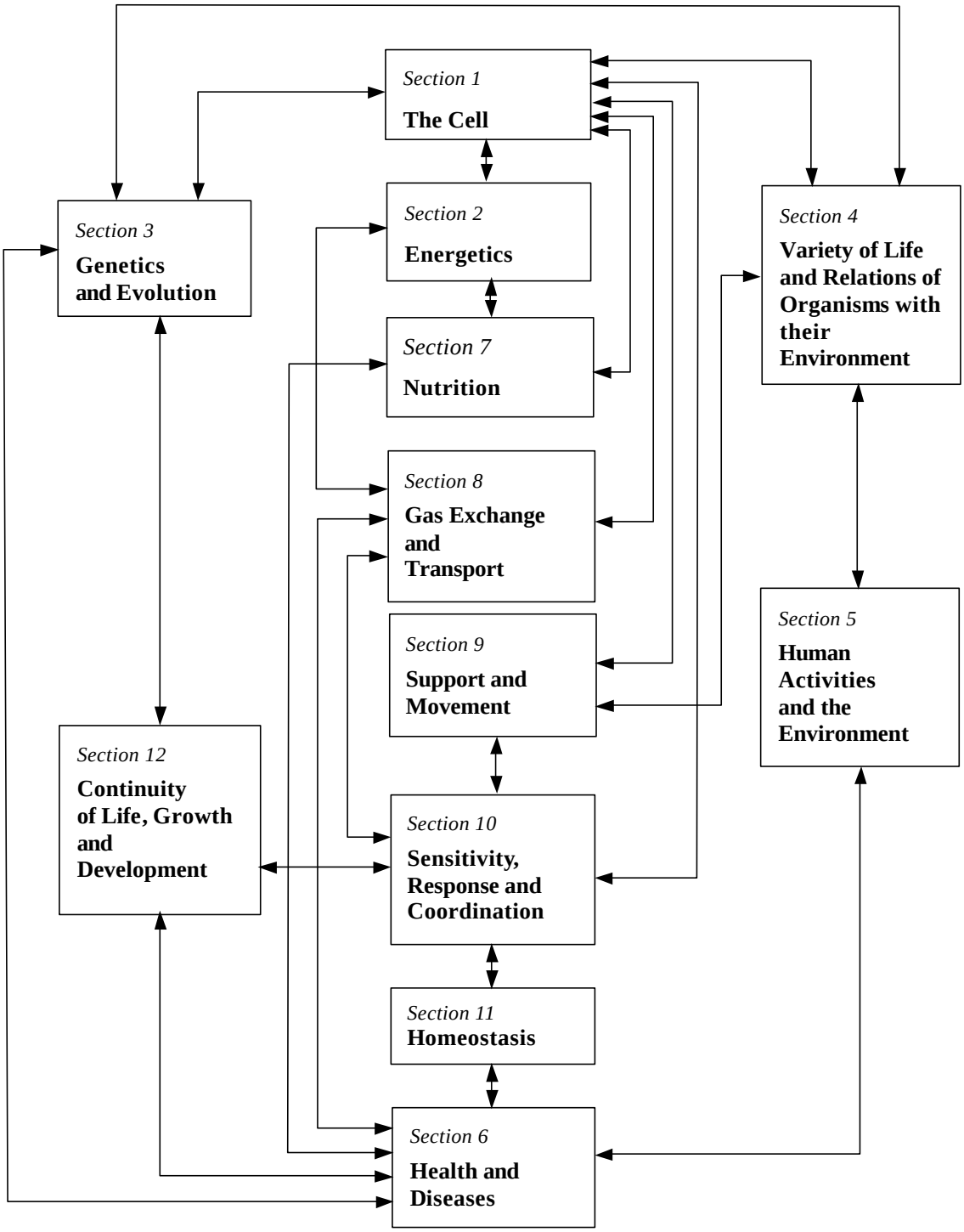
		No. of periods
Section 1	**The Cell** 1.1 Chemical constituents 1.2 Cell structure 1.3 Transport of substances in and out of the cell 1.4 Enzymes	44
Section 2	**Energetics** 2.1 Photosynthesis 2.2 Chemosynthesis 2.3 Respiration	32
Section 3	**Genetics and Evolution** 3.1 Genetics 3.2 Evolution	46
Section 4	**Variety of Life and Relations of Organisms with their Environment** 4.1 Variety of life 4.2 Classification 4.3 Ecology	38
Section 5	**Human Activities and the Environment** 5.1 Human impact on the environment 5.2 Human responsibility for environmental conservation	22
Section 6	**Health and Diseases** 6.1 Some factors affecting health 6.2 Transmission of pathogens and prevention of infection 6.3 Defence against pathogens 6.4 Some non-infectious diseases	30
Section 7	**Nutrition** 7.1 Modes of nutrition 7.2 Nutrients required by photosynthetic plants 7.3 Heterotrophic nutrition	18

Section 8	**Gas Exchange and Transport** 8.1 Gas exchange 8.2 Transport	38
Section 9	**Support and Movement** 9.1 Support in animals 9.2 Movement in animals 9.3 Support in plants 9.4 Movement in plants	20
Section 10	**Sensitivity, Response and Coordination** 10.1 Detection of environmental conditions in mammals 10.2 Nervous coordination in mammals 10.3 Hormonal coordination in mammals 10.4 Response to the environment in flowering plants	28
Section 11	**Homeostasis** 11.1 Homeostasis 11.2 Water balance 11.2 Regulation of body temperature 11.3 Regulation of blood glucose level	16
Section 12	**Continuity of life, Growth and Development** 12.1 Reproduction 12.2 Growth and development	30
Section 13	**Practical work (subsumed in the teaching periods suggested for Sections 1-12.)**	
	Total:	**362**
	(Equivalent to 241 hours)	

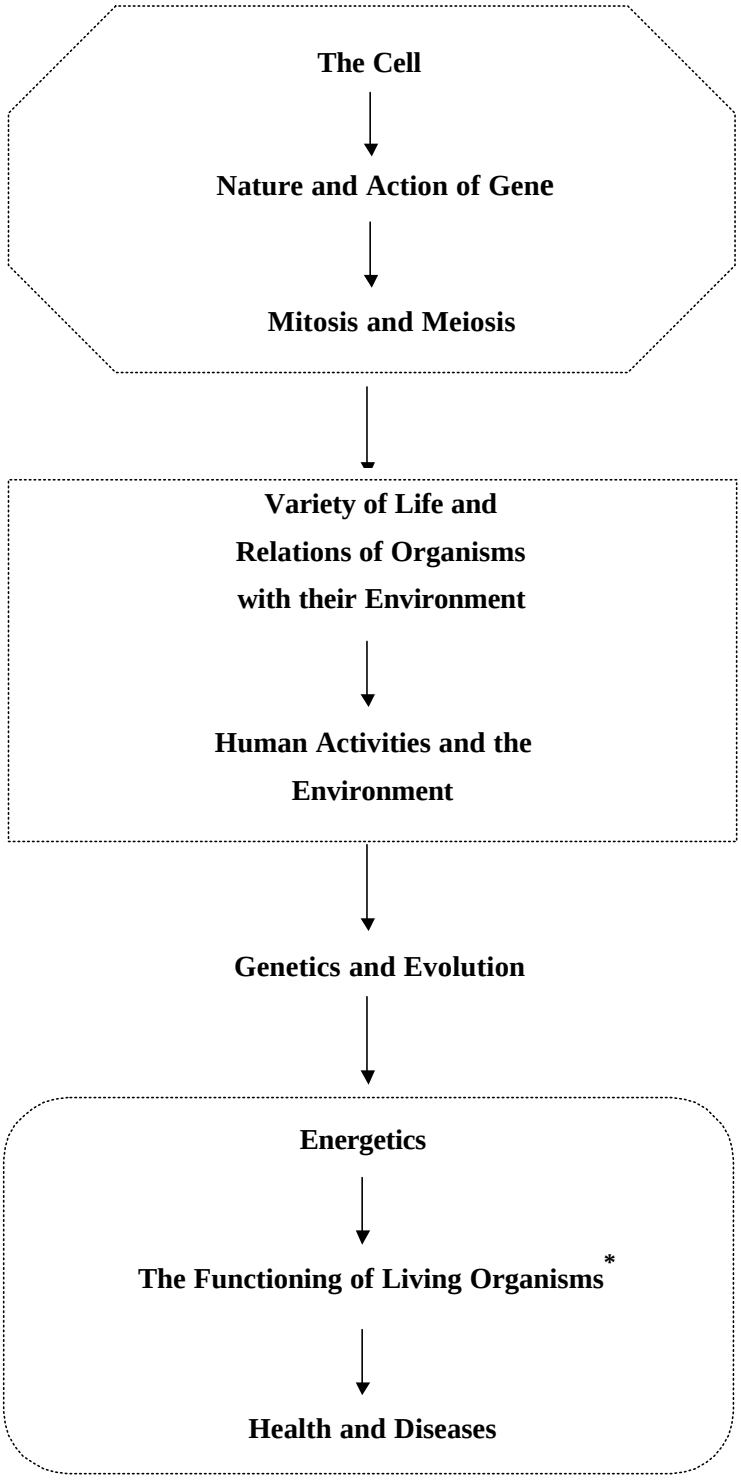
C. Teaching sequence

The order of teaching the different parts of the curriculum will depend very much on the teachers' individual preference and approach to the subject. Teachers may find the following information helpful in the planning of their own teaching schedules. The major relationship between sections is summarised in the flow chart below. Some suggested teaching sequences are also given in the pages that follow.

The Major Relationship Between Sections

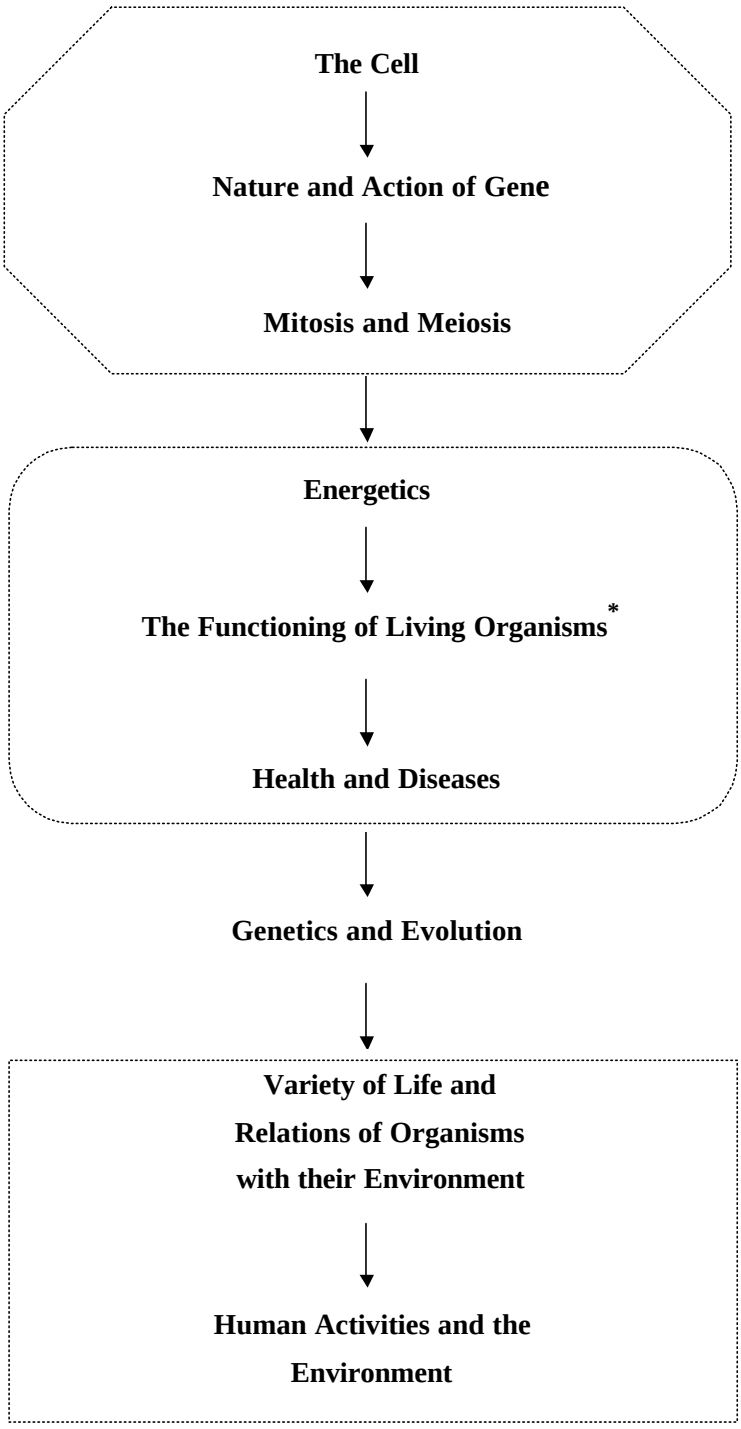


Suggested Teaching Sequence A



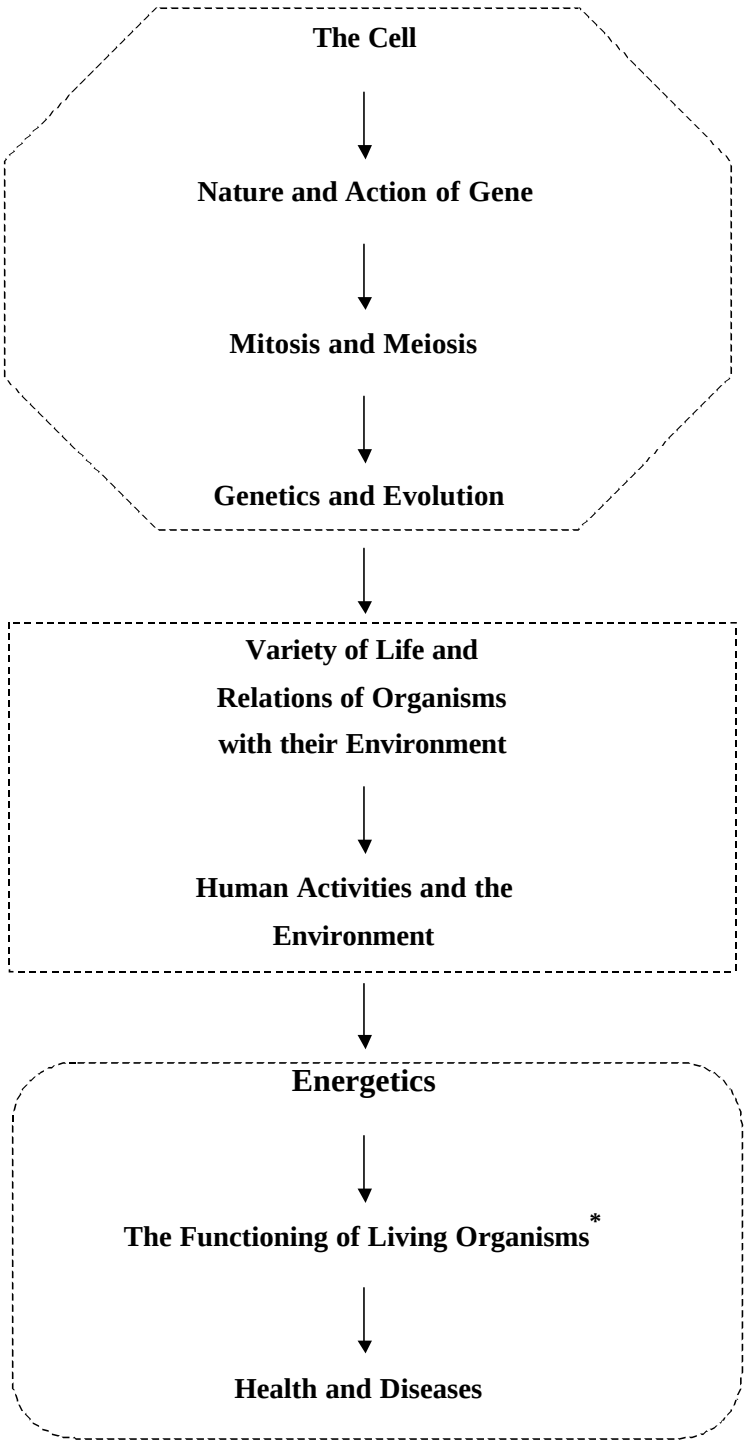
***The Functioning of Living Organisms** comprises of *Nutrition; Gas Exchange and Transport; Sensitivity, Response and Coordination; Support and Movement; Homeostasis; and Continuity of Life, Growth and Development.*

Suggested Teaching Sequence B



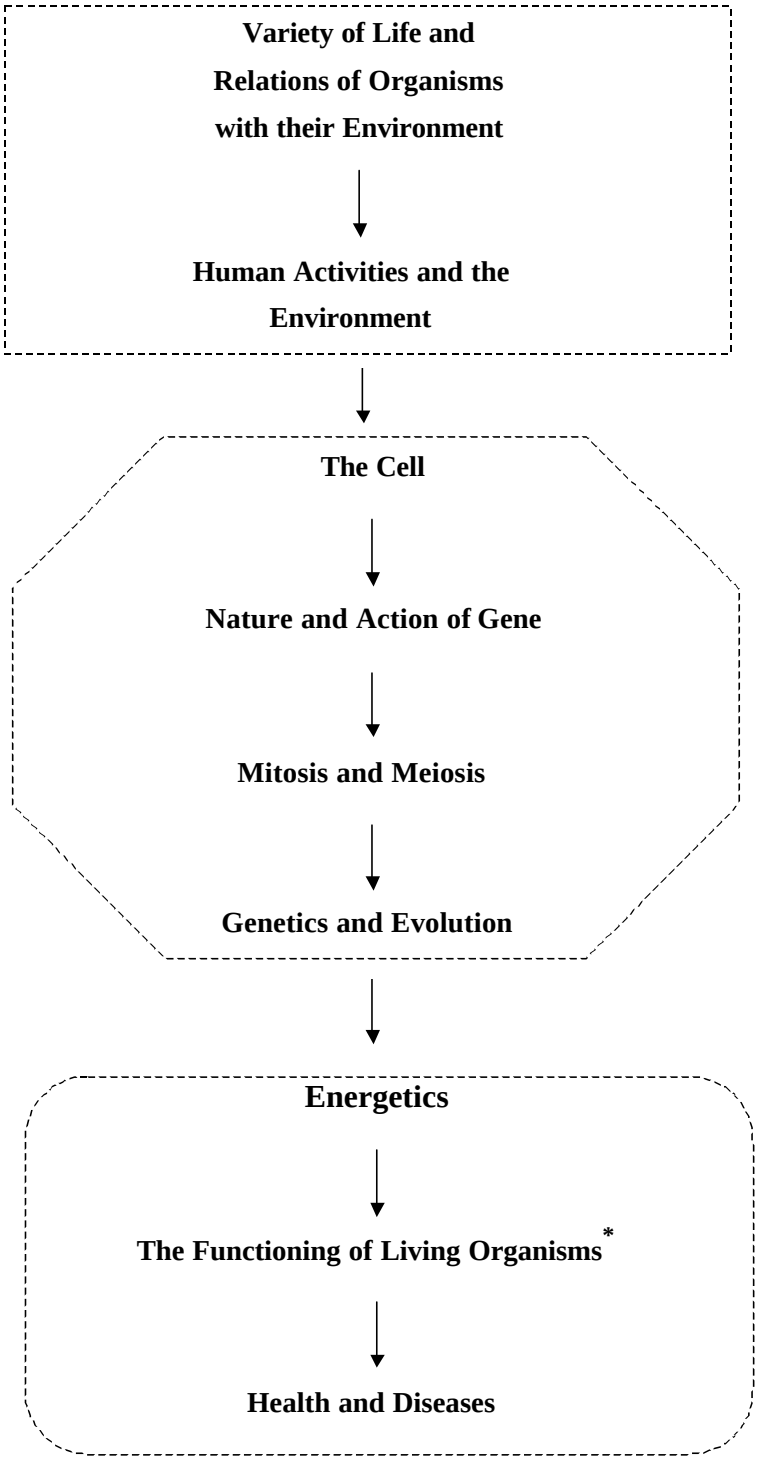
***The Functioning of Living Organisms** comprises of *Nutrition; Gas Exchange and Transport; Sensitivity, Response and Coordination; Support and Movement; Homeostasis; and Continuity of Life, Growth and Development.*

Suggested Teaching Sequence C



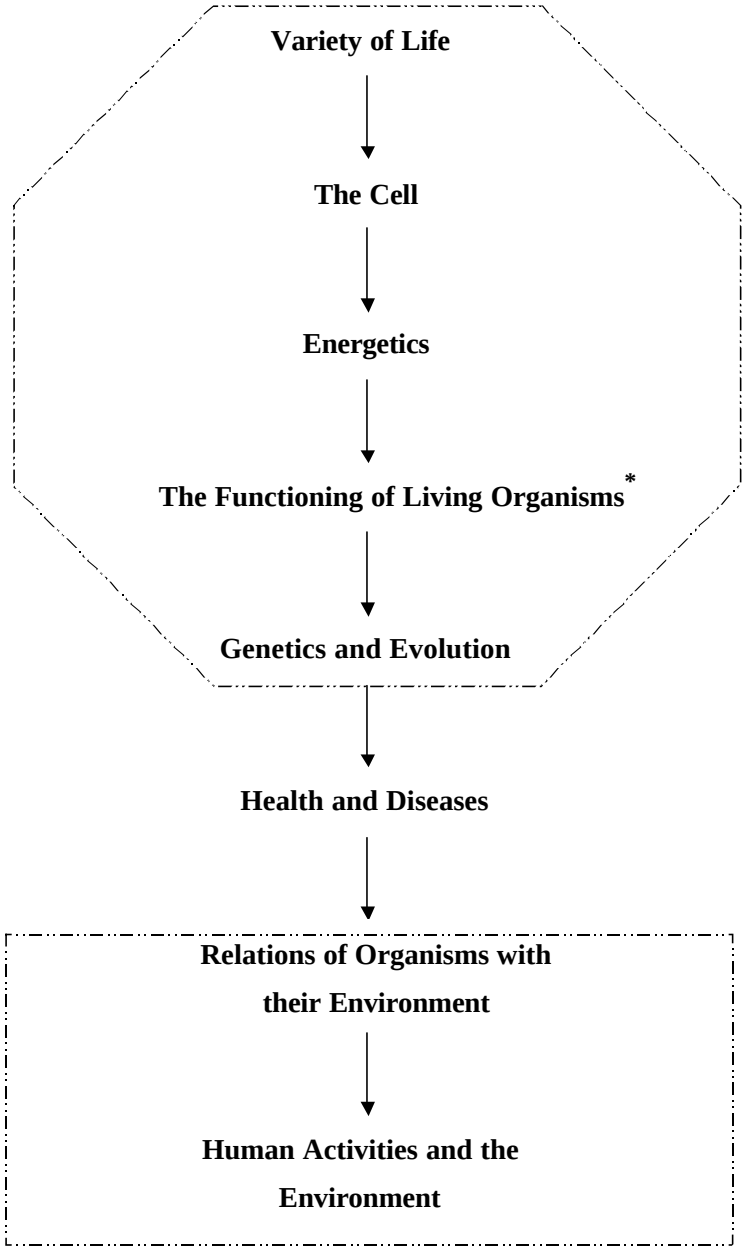
***The Functioning of Living Organisms** comprises of *Nutrition; Gas Exchange and Transport; Sensitivity, Response and Coordination; Support and Movement; Homeostasis; and Continuity of Life, Growth and Development.*

Suggested Teaching Sequence D



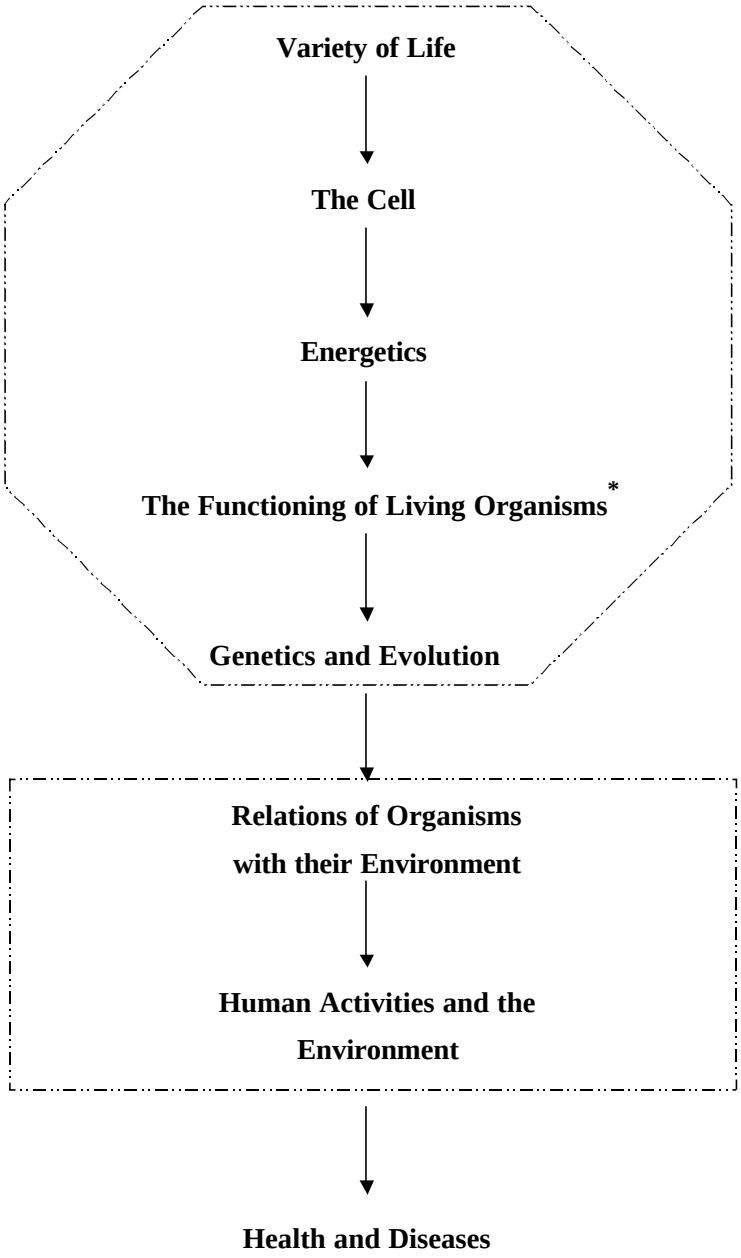
***The Functioning of Living Organisms** comprises of *Nutrition; Gas Exchange and Transport; Sensitivity, Response and Coordination; Support and Movement; Homeostasis; and Continuity of Life, Growth and Development.*

Suggested Teaching Sequence E



***The Functioning of Living Organisms** comprises of *Nutrition; Gas Exchange and Transport; Sensitivity, Response and Coordination; Support and Movement; Homeostasis; and Continuity of Life, Growth and Development.*

Suggested Teaching Sequence F



***The Functioning of Living Organisms** comprises of *Nutrition; Gas Exchange and Transport; Sensitivity, Response and Coordination; Support and Movement; Homeostasis; and Continuity of Life, Growth and Development.*

D. Content

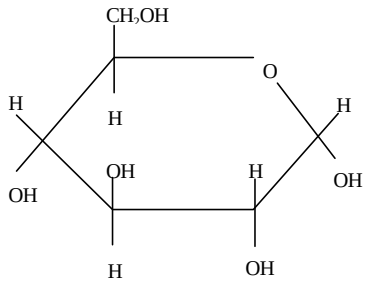
Section 1 The cell

Section 1 aims to provide students with an extended understanding of the roles of the biological molecules, and to reinforce the concept that the cell is the fundamental unit of structure and function in living organisms.

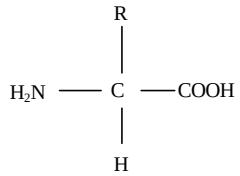
Having learnt about the importance of carbohydrates, fats and proteins as food substances in S4-5, students will have a further understanding of the different roles of these biological molecules in living organisms. Together with the study of the roles of nucleotides and nucleic acids, students are prepared to the biochemical approach to the study of *Energetics (Section 2)*, and *Nature and action of the gene (Section 3)*.

The structure-function relationships of cells, cell organelles and membranes are studied. This paves the way to the understanding of the intricacies of energy conversion processes in *Section 2*, making it possible to relate some of these metabolic processes to the structures of a cell.

Knowledge of transport across membranes helps students to understand *Gas exchange* in organisms *(Section 8)*, *Absorption and transport of water and mineral salts* in flowering plants *(Section 8)* and *Transmission of nerve impulse (Section 10)*. Coupled with topics on *Chemical constituents* and *Enzymes*, this section would also lead to a more thorough understanding of *Digestion* and *Absorption* in *Heterotrophic nutrition (Section 7)*.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
1.1 Chemical constituents **1.1.1 Carbohydrates** • the chemical structure of glucose as:  	• Explore students' ideas about the chemical composition of carbohydrates. • Use models or audiovisual materials to show the structure of carbohydrates.	• recognise the chemical structure of glucose.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the types of carbohydrates: monosaccharides (hexose and pentose), disaccharides (sucrose and maltose) and polysaccharides (cellulose, starch and glycogen).	• Ask students to list different types of carbohydrates.	• give examples of the different types of carbohydrates.
• the formation of glycosidic bond.	• Use ball-and-stick model to illustrate the formation of glycosidic bond.	• state that monosaccharides can be linked by glycosidic bond.
• the function of carbohydrates as an energy source: glucose as an immediate energy source, starch and glycogen as storage compounds. • the function of carbohydrates as structural materials: cellulose as component of cell wall.	• Explore students' prior knowledge on the functions of carbohydrates.	• state the functions of carbohydrates.
• the functions of starch and cellulose in relation to their molecular structures, with a brief reference to α- and β- linkages.		• appreciate that a small difference in molecular structure could lead to a great difference in function. • state the importance of carbohydrates in organisms.
1.1.2 Lipids		
• the basic components of triglycerides.	• Explore students' ideas about the chemical composition of lipids.	• state the basic components of triglycerides.
• the function of lipids as an energy source: triglycerides as storage compounds. • the function of lipids as structural components: phospholipids as components of membranes.	• Explore students' prior knowledge on the functions of lipids.	• state the functions of lipids.
• the function of lipids as regulatory substances, with an awareness of cholesterol as a precursor of steroid hormones (e.g. sex hormones) and vitamin D.	• Search for information on the sources and importance of cholesterol.	• state the importance of lipids in organisms.
1.1.3 Proteins		
• amino acids as the monomers that make up proteins.	• Explore students' ideas about the chemical composition of proteins.	• describe the structure of proteins.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the chemical structure of amino acid as:  		• recognise the chemical structure of amino acid.
• peptide bonds and polypeptide chains. • the 3-dimensional conformation of proteins: its ultimate dependence upon amino acid sequence and its functional significance.	• Use models or audiovisual materials to show the structure of proteins.	• explain the relationship between amino acid sequence and the 3-dimensional conformation of proteins. • describe the functional significance of the 3-dimensional conformation of proteins.
• the functions of proteins: as structural components, e.g. in cell membrane and cytoplasm. • the roles of proteins as enzymes, hormones and antibodies.		• relate the functions of proteins to their chemical structure. • state the importance of proteins in organisms.
	• Use food tests (e.g. Benedict' s test, iodine test, grease spot test, Sudan test and biuret test) to identify food substances in a range of biological materials, including solutions, suspensions and sections. These tests can be done quantitatively whenever appropriate. • Design and perform investigations to identify and analyse the occurrence of food substances in foods and other biological materials.	
1.1.4 Nucleotides and nucleic acids		
• the basic components of nucleotides. • mononucleotides: ATP (adenosine triphosphate) as an energy carrier. • dinucleotides: NAD (nicotinamide adenine dinucleotide) as a coenzyme. • polynucleotides: RNA (ribonucleic acid) and DNA (deoxyribonucleic acid).	• Use models or audiovisual materials to show the structure of DNA.	• state the basic components of nucleotides. • outline the roles of mononucleotides, dinucleotides and polynucleotides in metabolism.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
1.1.5 Inorganic components		• distinguish between carbohydrates, triglycerides, proteins and nucleic acids according to their chemical structures.
• the presence of inorganic ions in cells.	• Discuss the possible roles of inorganic ions in cells. • Discuss the possible benefits of drinking mineral water or isotonic drinks.	• give examples of inorganic ions in cells. • appreciate the importance of inorganic ions.
• the biological significance of water in relation to its properties.	• Discuss whether life can exist without water.	• explain why water is important to life.
1.2 Cell structure		
• the variety of cell structure and function as exemplified by the following: leaf epidermis, parenchyma, collenchyma, sclerenchyma, phloem, xylem, epithelia (squamous, ciliated and stratified), blood cells and neurones.	• Provide students with a variety of biological materials, such as sections, whole mounts, macerated plant materials, and blood smear. Ask students to make observations using light microscope and to record them as drawings using annotation. • Use sample drawings to illustrate the criteria of good high power drawings. • Prepare temporary mounts of leaf epidermis (e.g. onion, *Zebrina* sp., *Rhoeo discolor*), free-hand sections of herbaceous stems and use simple staining techniques where appropriate. • Measure cell size using a light microscope with a micrometer graticule, or other means.	• identify the special features of different types of cells. • relate these special features to the functions of the cells.
• the ultrastructures and their functions in plant and animal cells: nucleus, cell wall, cell membrane, vacuole, chloroplast, mitochondrion, lysosome, ribosome, endoplasmic reticulum and Golgi apparatus.	• Guide students to interpret electron micrographs and work out the size of cell organelles.	• relate the structure of cell organelles to their functions. • interpret electron micrographs and estimate the size of cell organelles.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the fluid mosaic model of membranes. • the structure of prokaryotic cells and eukaryotic cells.	• Use a tank, ping-pong balls, pieces of foam and water to construct a fluid mosaic model of the membrane. • Guide students to list the similarities and differences between prokaryotic cells and eukaryotic cells by examining electron micrographs.	• use the fluid mosaic model to explain the properties and functions of membranes. • appreciate the use and limitations of scientific models. • compare the cellular organisation of prokaryotic and eukaryotic cells.
1.3 Transport of substances in and out of the cell • the selective permeability of membranes. • the destruction of membranes at high temperatures and by some chemicals, e.g. chloroform, ethanol. • the processes of diffusion, osmosis and active transport. • the processes of pinocytosis and phagocytosis. • turgor and plasmolysis in plant cells with reference to water potential, solute potential and pressure potential.	• Guide students to design investigations to study the effects of temperature and chemicals on membrane permeability; ask students to suggest suitable biological materials to be used for these studies. • Use materials such as the red lower epidermis of the leaves of some ornamental plants (e.g. *Zebrina* sp. or *Rhoeo discolor*) to show plasmolysis of plant cells. • Use materials such as the epidermis of onion scale leaves and potato tuber tissue to determine the solute potential or water potential of plant cells.	• explain the selective permeability of membranes. • explain how substances can move across membranes by various processes. • use the concept of water potential to explain or predict biological phenomena.
1.4 Enzymes • the protein nature of enzymes. • the role of enzymes as catalysts in lowering activation energy through the formation of enzyme-substrate complex. • the concept of active site and enzyme specificity. • the induced-fit model of enzyme action.		• state the roles of enzymes in metabolism. • use the concepts of active site and induced-fit model to explain the action of enzyme. • appreciate the impermanent nature of scientific theories with reference to the development of the understanding of the nature of enzyme action.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the effects of temperature, pH, enzyme concentration and substrate concentration on the rate of enzymatic reactions. • the effects of cofactors, reversible inhibitors (competitive and non-competitive) and irreversible inhibitors on the rate of enzymatic reactions. • end-product inhibition.	• Guide students to design investigations to study the effects of different factors on the rate of enzymatic reactions. Suitable enzymes include amylase, urease, catalase, pepsin, sucrase. (Where possible, at least some of the enzymes used should be obtained from living tissues and/or commercial products, e.g. biological washing powder and meat tenderiser.)	• describe and explain the effects of various factors on the rate of enzymatic reactions.
• the application of enzymes, e.g. biological washing powder and meat tenderiser.	• Explore students' knowledge of the use of enzymes in everyday life.	• give examples of the applications of enzymes in everyday life. • explain how enzymes work in household products.

Section 2 Energetics

Respiration is the process by which energy is released in living cells through the controlled oxidative breakdown of organic food materials. Organisms may have to synthesise these organic food materials using energy from the sun (photosynthesis) or from the oxidation of inorganic materials (chemosynthesis).

This section aims to extend students' understanding of the concepts of energy transformation in photosynthesis and respiration. An outline of their energy conversion processes, including an insight into their interrelationship, should be discussed. But details of the metabolic pathways, names of intermediates and individual enzymes should be de-emphasised. Chemosynthesis should be stressed as a process using an alternative source of energy to light, thus forming a solitary exception to the much-accepted concept that energy needed by living organisms comes ultimately from the Sun.

This section builds on prior knowledge in *Section 1*: *Cell structure* (especially the ultrastructures of chloroplasts and mitochondria), *Chemical constituents* and *Enzymes.* It prepares students for an understanding of the role of energy in supporting physiological processes discussed in the other sections, and provides them with a foundation for the study of *Energy flow and nutrient cycling (Section 4).*

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
2.1 Photosynthesis		
• the importance of photosynthesis in converting light energy to chemical energy.	• Discuss what would happen to the living world if all photosynthetic organisms disappeared from the Earth.	• explain the importance of photosynthetic organisms as producers.
2.1.1 Site of photosynthesis		
• the structure of dicotyledonous leaves in relation to photosynthesis.	• Ask students to collect a variety of broad leaves. Guide them to list out the common morphological features of the leaves and relate them to photosynthesis. • Examine a section of a dicotyledonous leaf microscopically to study its structure in relation to photosynthesis.	• describe the adaptive features of leaves to photosynthesis.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the structure of chloroplast as shown in electron micrographs. [Refer to Section 1.2.]		• relate the structure of chloroplast to its functions in photosynthesis.
• the occurrence of different pigments in the chloroplast.	• Extract leaf pigments with extracting solvent, and separate them by paper chromatography.	
• the absorption spectra of chlorophyll pigments and the action spectrum of photosynthesis.	• Show pictures of the spectrum of white light passing through a prism and the spectrum of white light passing through a chlorophyll extract and a prism. Guide students to deduce the light absorption property of chlorophyll.	• relate the absorption spectra of chlorophyll pigments to the action spectrum of photosynthesis.
2.1.2 Photochemical reactions		
• an outline of the photochemical reactions: (1) electrons in chlorophylls are excited by light energy, without referring to photosystems I and II;	• Use audiovisual materials to illustrate the photochemical reactions. • Discuss the importance of the photochemical reactions.	• outline the main steps of photochemical reactions. • explain the importance of photochemical reactions. • outline the principle of photophosphorylation.
(2) energy from these excited electrons generates ATP;		• relate biochemical pathways of photosynthesis to their sites in cells.
(3) photolysis of water provides hydrogen for the reduction of NADP (nicotinamide adenine dinucleotide phosphate) and oxygen gas is released.	• Discuss how the establishment of photosynthesis might have led to the evolution of aerobic organisms. • Construct a flow chart to show the process of photochemical reactions.	
2.1.3 Carbon fixation		
• an outline of the Calvin cycle to show that: (1) carbon dioxide is accepted by a 5-C compound to form two molecules of a 3-C compound;	• Read how Calvin used radioactive isotopes to trace the path of carbon atoms in photosynthesis. • Construct a flow chart to show the process of carbon fixation.	• outline the main steps of carbon fixation. • point out the dependence of this process to the photochemical reactions.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
(2) reduction of the 3-C compound by reduced NADP to triose phosphate, some of which combine to yield hexose phosphate which is subsequently metabolised to sucrose and starch; (3) metabolism of some of the triose phosphate to provide a continuous supply of the 5-C carbon dioxide acceptor. • that triose phosphate can be used as a substrate to produce lipids and amino acids.		• describe the fates of triose phosphate.
2.1.4 Factors affecting the rate of photosynthesis		
• the effects of light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis.	• Ask students to predict the possible effects of various factors on the rate of photosynthesis. Guide students to design and perform investigations to test their ideas.	• describe and explain the effects of various factors on the rate of photosynthesis.
• the concept of limiting factors, as exemplified by light intensity and carbon dioxide concentration.	• Perform experiments to study the factors affecting the rate of photosynthesis using a bubbler / syringe, J-tube or a data logger with oxygen or pressure sensors.	• explain the concept of limiting factors.
• the principle for maximising plant growth in greenhouse by the control of light, temperature and carbon dioxide concentration.	• Discuss how to increase the yield of plants through the design of a greenhouse.	• apply the concept of limiting factors in the design of a greenhouse.
2.2 Chemosynthesis		
• the general nature of chemosynthesis using nitrifying bacteria as an example.	• Search for information on the importance of other types of bacteria in the maintenance of the ecosystem.	• realise the occurrence of chemosynthesis. • point out the difference between chemosynthesis and photosynthesis.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
2.3 Respiration		
• the importance of respiration in converting chemical energy in food to chemical energy in ATP.		• define respiration. • compare respiration and photosynthesis.
2.3.1 The sites of respiration		
• the sites of the various biochemical pathways of respiration.		• state the sites of different stages of respiration.
• the structure of mitochondrion as shown in electron micrographs. [Refer to Section 1.2.]	• Use electron micrographs to show the structure of mitochondrion.	• relate the structure of mitochondrion to its function.
2.3.2 Glycolysis		
• an outline of glycolysis to show: (1) the phosphorylation of glucose; (2) the break down of hexose phosphate to triose phosphate; (3) the conversion of triose phosphate to pyruvate with the production of reduced NAD and ATP.	• Construct a flow chart to show the process of glycolysis. • Read how scientists worked out the glycolytic pathway.	• describe the main steps of glycolysis. • point out the significance of glycolysis.
2.3.3 Aerobic pathway		
• the conversion of pyruvate to acetyl-CoA. • an outline of the Krebs cycle to show: (1) the combination of acetyl-CoA with a 4-C compound to form a 6-C compound; (2) that the 6-C compound undergoes a series of reactions to regenerate the 4-C compound with the release of carbon dioxide; (3) the production of reduced NAD and ATP.	• Construct a flow chart to show the aerobic pathway. • Discuss the ways to measure the rate of aerobic respiration. Then conduct investigations to find the rate of aerobic respiration in plants and animals, e.g. germinating seeds and mealworms.	• describe the main steps of Krebs cycle. • review the interrelationships between glycolysis, Krebs cycle and electron transport chain. • state the importance of Krebs cycle.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• that lipids and proteins can be used to produce reduced NAD and ATP. • the electron transport chain as a process of oxidative phosphorylation; the role of molecular oxygen as the final electron acceptor.		• point out the alternative substrates for respiration.
2.3.4 Anaerobic pathway • the fate of pyruvate under anaerobic condition. • the formation of lactic acid in muscle; the oxygen debt. • the formation of ethanol and carbon dioxide in yeast.	• Design and perform investigations to find the rate of anaerobic respiration in yeast. • Search for information on the brewing of beer and wine making.	• outline the biochemical pathways of alcoholic fermentation and lactic acid fermentation. • suggest how the knowledge of anaerobic respiration can be used in everyday life.
2.3.5 Energy yield • the comparison of the energy yield of aerobic and anaerobic respiration, without calculating the number of ATP produced.		• compare the energy yield of aerobic and anaerobic respiration.
2.3.6 Role of ATP • the role of ATP in energy transfer.		• explain the role of ATP in energy transfer.

Section 3 Genetics and Evolution

Section 3 aims to link together the understanding of the principles of genetics, the nature and behaviour of chromosomes and the role of genes at the molecular level. They form the basis of current and future genetic applications.

Controversial issues related to the applications of genetics should be evaluated critically in the light of their societal and ethical implications for the future well being of humankind. The historical development of genetic concepts and ideas, progressing to some of the breakthroughs and milestones of biology, should be introduced so as to give students some insights into the nature and methods of scientific investigation. This section closes with the mechanism of evolution, which should be discussed constructively and impartially against the evidence available, pointing out the inadequacy of science to provide complete answers.

This section extends the learning of *Nucleic acids* in *Section 1*. Students should be able to relate genetics to evolution and to relate these to other pertinent sections of this curriculum such as *Health and Diseases (Section 6)* and *Continuity of life, Growth and Development (Section 12).*

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
3.1 Genetics • about how the experiments of Mendel, Meselson and Stahl, etc., have contributed to the understanding of genetics.	• Read how some biologists (e.g. Mendel, Griffith, Hershey, Chase, Watson, Crick, Stahl, Meselson, Chargaff, Morgan) have contributed to our understanding of genetics.	• appreciate the historical development of genetic concepts and ideas. • appreciate that the development of scientific theories requires creative thinking and empirical support. • appreciate that the development of scientific knowledge is an ongoing process in which each generation of researchers gradually improves upon previous insights. • develop insights into the methods of scientific investigation.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
3.1.1 Nature and action of the gene		
• the structure and chemical nature of DNA to show its role as the genetic material. [Refer to Section 1.1.4.]	• Use models or audiovisual materials to illustrate the double helical structure of DNA. • Construct simple models of DNA using common materials (e.g. poppit beads, plasticine, cardboard, wire, pipe cleaners). • Extract DNA (e.g. DNA spooling) using living materials.	• state the role of DNA. • relate the structure of DNA to its role as the genetic material.
• the semiconservative nature of DNA replication: mechanism and evidence as illustrated by the work of Meselson and Stahl.	• Use models or audiovisual materials to illustrate the semiconservative mechanism of DNA replication.	• appreciate the process involved in scientific investigation.
• the features of the genetic code.	• Discuss with students how to use three letters to construct a large number of words.	• state the features of the genetic code.
• the roles of DNA and RNAs in protein synthesis.	• Use models or audiovisual materials to demonstrate the roles of DNA and RNAs in protein synthesis. • Construct more complex models of a section of DNA and a complementary mRNA molecule (e.g. using commercial kits).	• describe the process of protein synthesis. • explain how genes determine body characteristics.
• that genes can be turned on and off.		• realise that genes can be turned on and off.
3.1.2 Structure of chromosomes		
• the organisation of DNA into chromosomes in eukaryotic cells.	• Observe giant chromosomes (e.g. the salivary glands of *Chironomus* larvae) in squashed preparations or photomicrographs.	• distinguish between DNA and chromosomes.
3.1.3 Cell cycle		
• interphase: duplication of DNA • nuclear division (1) Mitosis : behaviour of chromosomes at prophase, metaphase, anaphase and telophase; the significance of mitosis.	• Observe and identify the different stages of mitosis using squashed tissues, prepared slides, or photomicrographs of root tip.	• describe the process of mitosis. • identify the different stages of mitosis.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
(2) Meiosis : behaviour of chromosomes during first and second divisions of meiosis including chiasma formation; crossing over; the significance of meiosis. • an outline of cytoplasmic division in animal and plant cells.	• Observe meiosis in plant and animal cells using prepared slides or photomicrographs.	• describe the process of meiosis. • compare the processes of mitosis and meiosis. • state and explain the significance of mitosis and meiosis. • point out that cell cycle consists of interphase, nuclear division and cytoplasmic division.
3.1.4 Inheritance of discrete characters		
• monohybrid and dihybrid crosses. (The pioneer work of Mendel should be referred to.) • backcross and test cross. • dominance and recessiveness. • Incomplete dominance (e.g. the colour of petals in snapdragon). • codominance (e.g. human blood group AB). • multiple alleles (e.g. human ABO blood groups). • sex-linked traits (e.g. haemophilia and red-green colour blindness).	• Discuss how Mendel conceived his theories on the basis of empirical evidence. • Study the results of monohybrid and dihybrid crosses to illustrate the patterns of inheritance. • Use computer simulation to study genetic crosses of some organisms (e.g. *Drosophila*). • Construct a pedigree of the inheritance of some human traits (e.g. ABO blood groups, tongue rolling, ear lobe of the family). • Use chi-square test to estimate the matching between observed and expected phenotypic outcomes. • Provide genetic problem to guide students to interpret and predict the results of genetic crosses.	• appreciate the importance of imagination and evidence in the formulation of hypotheses. • explain and predict inheritance patterns in monohybrid and dihybrid crosses. • state the use of backcross and test cross. • predict the possible phenotypes of the offspring in genetic cross. • state different patterns of inheritance from results of genetic crosses.
• linkage and crossing over.		• relate linkage of genes and crossing over to chromosomal behaviour during meiosis. • state the significance of crossing over.
3.1.5 Discontinuous and continuous variations		
• the factors contributing to variations between individuals within a species. • discontinuous variations (e.g. tongue rolling and ABO blood groups in humans) and continuous variations (e.g. height and weight in humans).		• realise that variations occur. • explain how mutation, meiosis and fertilisation may lead to genetic variations. • evaluate the importance of genetic factors and environmental factors in causing variations.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the normal distribution curve. • the use of standard deviation as a measure of the variation of a sample.	• Collect and analyse data on continuous and discontinuous variations using appropriate statistical software.	• demonstrate statistical skills in data analysis.
• the outline of polygenic inheritance and the effects of environment on it.		• outline polygenic inheritance. • state the effects of environment on phenotypes.
3.1.6 Mutation		
• gene mutation: the effect of gene mutation on amino acid sequence (e.g. sickle-cell anaemia). • chromosome mutation: changes in chromosome structure and chromosome number (e.g. Down syndrome).	• Display pictures showing the symptoms of some diseases caused by gene mutation and chromosome mutation. • Show photomicrographs of karyotypes of chromosome mutation.	• point out that mutation can take place at different levels.
• the types of mutation: spontaneous and induced mutations. • that mutations can be enhanced by ionising radiations and chemicals. [Refer to Section 6.]	• Use available evidence to assess the nature of risks involved in exposure to mutagens. • Discuss the precautionary measures in using X-ray in medical examination. • Search for information on the sources of mutagenic agents and their effects on human health.	• state the different causes of mutation. • practise ways to minimise the risk of developing mutation. • develop a concern for the proliferation of mutagenic agents.
• significance of mutation.		• explain the importance of mutation in the mechanism of evolution.
3.1.7 Applications of genetics		
• human genetics: (1) Pedigree analysis (e.g. colour blindness).	• Analyse pedigrees to trace the inheritance of some human traits.	• apply the principles of genetics in pedigree analysis.
(2) Genetic screening (e.g. detection of Down syndrome).	• Search for information on the kinds of genetic diseases that can be detected by screening test. • Conduct a small survey or project on the available screening services for the detection of common genetic diseases in Hong Kong.	• appreciate the use of genetic screening in detecting some genetic diseases.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
(3) Prenatal and postnatal counselling of genetic diseases (e.g. glucose–6–phosphate dehydrogenase deficiency and thalassaemia).	• Search for information on the provision of prenatal and postnatal counselling of genetic diseases in Hong Kong. • Visit a prenatal and postnatal genetic counselling check-up clinic.	• develop an awareness of the importance of genetic counselling.
(4) Gene therapy as a potential treatment of genetic diseases (e.g. cystic fibrosis).	• Search for information on examples of gene therapy and the prospects of gene therapy in relation to the Human Genome Project.	• appreciate the potential use of gene therapy.
(5) The implications of the Human Genome Project.	• Debate on the pros and cons of the Human Genome Project (HGP) or discuss the ethical and social concerns brought about by the HGP.	• discuss the contributions and concerns of the findings of the Human Genome Project.
• plant and animal breeding (1) Artificial selection and breeding for selected traits to produce desirable varieties. Hybrid vigour and polyploidy.	• Use audiovisual materials to show artificial insemination and cloning. • Search for information on selective plant breeding, e.g. miracle rice. • Search for information on modern technological advances in the selective breeding of domestic animals, e.g. the use of sperm banks, artificial insemination, and embryo transplants.	• appreciate the application of making appropriate genetic crosses to produce progeny with desirable traits. • explain the biological principles behind artificial selection.
(2) Cloning. [Refer to Section 12.]	• Read about tissue culture in plant cloning, e.g. orchid. • Search for information on animal cloning.	• appreciate the application of cloning in maintaining desirable traits in selected plants and animals.
• the outline of the principle of recombinant DNA technology and its applications.	• Use diagrams or flow charts to illustrate the principle of recombinant DNA technology.	• outline the principle of recombinant DNA technology. • cite examples of the applications of recombinant DNA technology.
• the outline of the principle of DNA fingerprinting, and its forensic use, e.g. parentage test.	• Carry out separation of DNA or polypeptides by electrophoresis. • Use audiovisual materials to illustrate the process of DNA fingerprinting.	• outline the principle of DNA fingerprinting. • state the applications of DNA fingerprinting.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• implications of genetic manipulation: the potential benefits, hazards and ethical issues.	• Examine cases or discuss the use of DNA fingerprinting in forensic science. • Debate on the pros and cons of genetic engineering or genetically modified food.	• discuss potential benefits, hazards and ethical issues related to genetic manipulation. • appreciate that genetic engineering has made possible the development of new biotechnologies and careers.
3.2 Evolution • the evidence of evolution: a brief assessment of fossils and homologous structures in pentadactyl limbs. The limitations and accuracy of fossil records. • the presence of other evidences of evolution, e.g. comparative anatomy, comparative biochemistry. • the mechanism of evolution: the roles of genetic variation, natural selection, and isolation in the development of new species.	• Display replicas or photographs of some fossils. • Read about the evolutionary development of modern horse. • Use the development of resistance in bacteria to certain antibiotics as an example to illustrate the concept of evolution. • Search for information on the phylogenetic significance of organisms which are considered to be "living fossils". • Read about the works of some biologists (e.g. Darwin and Lamarck) and their proposed theories of evolution. • Discuss the validity of the theory of natural selection. • Guide students to review the differences between scientific theories and other non-scientific modes of explanation, e.g. religious, metaphysical or philosophical, which have been a subject of considerable debate over the years.	• evaluate the use of fossil records and homologous structures as evidence for evolution. • point out the limitations of using fossil records. • develop an awareness of the other evidence of evolution. • describe the mechanism of evolution and speciation. • evaluate the theory of natural selection. • develop curiosity towards the origin of life.

Section 4 Variety of Life and Relation of Organisms with their Environment

Section 4 advocates the study of organisms in relation to their natural habitats, alongside with ecological field studies, in a local context. The purpose is to give students an appreciation both of biodiversity and of the way in which organisms are adapted to survive in their habitats. It extends the knowledge acquired in S4-5 and aims to further students' understanding of the interrelationships between organisms and between organisms and their environment. This section also introduces the binomial system of naming organisms and the concept of taxonomic hierarchy. Students are expected to have the ability to construct and use dichotomous keys to identify animals and plants based on their distinguishing external features.

Prior study of *Energetics (Section 2)* offers a foundation to the comprehension of energy flow and nutrient cycling. An integrated study of ecology with *Human Activities and the Environment (Section 5)* is conducive to the deepening of students' respect for living organisms, their respective habitats and the environment. The concepts of *Variation* and *Mechanism of evolution* (especially natural selection) learnt in *Section 3* may also be applied to explain the diversity and distribution of organisms within a habitat and in different habitats.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
4.1 Variety of life • the relationship between the diversity of organisms and the variety of their ways of life. • to use a range of organisms found in two different local habitats (preferably, one terrestrial habitat and one aquatic habitat) to illustrate how the organisms are adapted to their habitats and ways of life.	• Use specimens or audiovisual materials to illustrate the diversity of organisms, and their ways of life. • Study organisms (e.g. algae, ferns, gymnosperms, angiosperms including monocotyledonous plants and dicotyledonous plants, molluscs, annelids, echinoderms, cnidarians, arthropods, vertebrates) in relation to their natural habitats during field studies.	• appreciate the wonders of the living world and the ways in which organisms are adapted to their habitats during field studies.
4.2 Classification • that modern classification is based on the phylogenetic relationships of organisms.		• state that the classification system is subject to change as new evidences appears.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the grouping of organisms into five kingdoms: Prokaryotae, Protoctista, Fungi, Plantae and Animalia; the characteristics of each kingdom. • the binomial system of naming organisms and the concept of taxonomic hierarchy: kingdoms, phyla/divisions, classes, orders, families, genera and species.	• Challenge the basis of the five kingdoms system, and consider alternative classification systems.	• distinguish among the five kingdoms. • classify unknown specimens into the five kingdoms. • explain the system of binomial nomenclature and the taxonomic hierarchy.
• to use external features to construct keys and use them to identify organisms to any level.	• Construct dichotomous keys using distinguishing external features of organisms e.g. Arthropoda (Classes Crustacea, Insecta, Arachnida and Myriapoda). • Use dichotomous keys to identify plants and animals based on external features.	• construct and use dichotomous keys.
4.3 Ecology **4.3.1 Ecosystem**		
• the meaning of the terms: biosphere, biome, ecosystem, community and population.	• Show audiovisual materials of various biomes and ecosystems. • Ask students to draw a concept map to illustrate the interrelationship among biosphere, biome, ecosystem, community and population.	• define biosphere, biome, ecosystem, community and population and describe their interrelationship.
• the concept of habitat and niche of an organism. • an outline of population growth and the factors affecting it.	• Guide students to investigate population growth, e.g. yeast. • Design and perform investigations to study factors affecting population growth.	• distinguish between habitat and niche. • state the factors that affect population growth. • analyse and interpret data on population growth.
• an outline of biotic and abiotic factors in ONE local ecosystem and their effects on the distribution and abundance of organisms in that ecosystem.	• Propose hypotheses to explain the effects of abiotic and biotic factors on the distribution and abundance of organisms in a habitat. Design and perform experiments to test the hypotheses.	• explain the possible effects of biotic and abiotic factors on the distribution and abundance of organisms.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
	• Ask students to describe the physical features of one habitat, identify environmental factors that have a major impact on the distribution of organisms, and discuss how organisms adapt to such conditions.	
• the use of an appropriate sampling method, such as the quadrat, line transect and belt transect, to study the distribution and abundance of organisms.	• Study the distribution of lichens on a tree trunk or boulder. • Conduct an ecological study of a local habitat to measure the physical factors of the environment, and to find out the distribution of plants and animals, using appropriate sampling methods in the field.	• work in small groups in ecological studies. • use appropriate sampling methods and develop an awareness of their limitations. • communicate their ideas through ecological reports.
4.3.2 Energy flow and nutrient cycling		
• the transfer of energy between different trophic levels and its relative efficiency; the importance of producers, consumers (including detritivores) and decomposers in the cycling of nutrients. • the concepts of food chain, food web and trophic level; the pyramid of numbers, pyramid of biomass, and pyramid of energy.	• Provide students with a selected list of animals and plants for a chosen habitat, and ask students to suggest their feeding relationships or trophic level. • Challenge students to find out as many food chains as possible within one ecosystem. Hence construct a food web using these food chains.	• explain the flow of energy within an ecosystem. • assess the efficiency of energy transfer between trophic levels. • relate the concept of energy flow between different trophic levels to photosynthesis, respiration and chemosynthesis. • explain the roles of producers, consumers (including detritivores) and decomposers in the cycling of nutrients. • appreciate the importance of photosynthetic organisms in an ecosystem.
• the nitrogen and carbon cycles.	• Use audiovisual materials to illustrate nitrogen and carbon cycles. • Construct concept maps to show the nitrogen or carbon cycles.	• state the major stages of the nitrogen and carbon cycles. • evaluate the importance of the nitrogen and carbon cycles.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
4.3.3 Interdependence of organisms		
• the interactions between organisms: predation, competition, commensalism, mutualism and parasitism.	• Ask students to search for posters, photographs, pictures, video clips, preserved or live specimens, and ask them to identify features of the interactions. • Provide data for students to analyse the interactions of organisms. • Use computer programmes to simulate the effects of the interactions between organisms over time.	• identify different interactions between organisms. • explain how these interactions maintain the balance of nature. • evaluate how human interference may disrupt such balance.
4.3.4 Succession		
• a simple account of ecological succession, including primary and secondary succession, and climax community.	• Observe different types of vegetation communities in the uplands of Hong Kong to illustrate the transitional stages in succession. • Observe the colonisation of wastelands (e.g. by grasses and herbs).	• outline the process of ecological succession. • develop an awareness of the effects of human interference on succession.

Section 5 Human Activities and the Environment

Rapid human population growth necessitates an increased demand for food, space and other needs, e.g. recreation. This section explores the far-reaching effects of agriculture, urbanisation and industrialisation on the environment. The global issues of ozone depletion, global warming and acid rain should be addressed not as isolated symptoms but as evidence of integrated stresses that human activities have placed on the global ecosystem. The concept of sustainable development, the need for conservation, the relationship between economic development and the protection of the environment, and the framework under which conservation is effected both locally and globally are also considered.

Students should be able to integrate the knowledge of *Ecology (Section 4)* with this section to evaluate the impact of human activities on the interactions of organisms and their environment. They should be encouraged to discuss, debate or report on those aspects of the local environment that have been affected by people and propose realistic solutions to the problems that exist. Developing a healthy attitude to "think globally and act locally" will stand them in good stead to become responsible citizens of Hong Kong and contributing inhabitants on Earth.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
5.1 Human impact on the environment		
5.1.1 Human population		
• the exponential growth of the human population and its control. • the impact of human population explosion on the environment.	• Discuss or carry out project work on the human population explosion and its impact on the environment; the world food problem as a biological and social issue. • Discuss the need and the strategies for human population control.	• describe the pattern of human population growth. • evaluate the impact of rapid human population growth on the environment. • appreciate the need for human population control.
5.1.2 Resource exploitation		
• the variety of resources exploited by humans: renewable (e.g. timber and fish) and non-renewable resource (e.g. fossil fuel).	• Ask students to make a list of renewable and non-renewable resources.	• give examples of renewable and non-renewable resources. • distinguish between renewable and non-renewable resources.
• that human exploitation of natural resources has modified the environment.	• Search for information on how human exploitation of natural resources has modified the environment.	• point out the impact of human activities on natural resources.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the risk of renewable resources (e.g. timber) becoming a limiting resource.	• Ask students to suggest examples of renewable resources that have become limiting due to human exploitation.	• adopt appropriate attitude and practice in the wise use of natural resources.
5.1.3 The effects of agriculture		
• deforestation as a means to clear land for agriculture and animal grazing.	• Collect newspaper clippings on cases of soil erosion and desertification as a result of land clearance, overgrazing and over-harvesting.	• point out the diminution of forest as an effect of agriculture.
• soil erosion as a consequence of inappropriate agricultural practices. • the undesirable effects of chemical control of pests and weeds, and the excessive use of chemical fertilisers.		• state and explain the undesirable effects of certain agricultural practices on the ecosystem.
5.1.4 The effects of urbanisation and industrialisation **5.1.4.1 Land clearance and reclamation**		
• the impact of land clearance and reclamation (for residential and urban infrastructure development) on the environment.	• Carry out a case study to illustrate the effect of land clearance or reclamation on the environment. • Debate on the pros and cons of the development of a local infrastructure.	• explain the ecological impact of land clearance and reclamation. • analyse the pros and cons of urban and industrial developments on the ecosystem.
5.1.4.2 Pollution		
• some major atmospheric pollutants (e.g. sulphur dioxide and particulates) and their effects.	• Search for information about the Air Pollution Index (API). • Conduct a small project or investigation on atmospheric pollution (e.g. acid rain, global warming, greenhouse effect, lichen distribution as an indicator of air pollution by sulphur dioxide). • Identify the most air-polluted area in Hong Kong based on the available information from the Environmental Protection Department.	• state the major atmospheric pollutants and their effects.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• global issues: ozone depletion, global warming and acid rain.	• Search for information and evidence on ozone depletion, global warming and acid rain. • Discuss the controversial views of global warming.	• explain the causes and effects of ozone depletion, global warming and acid rain. • state the roles of the individual in overcoming these problems.
• how inadequate treatment of sewage may lead to the deterioration of water quality and microbial hazards.	• Conduct a survey of a freshwater stream or seaside on the types, sources and effects of pollutants. • Compare the oxygen content of clean and polluted water using data loggers or other means. • Study the grading of beach water quality prepared by the Environmental Protection Department.	• explain the problems of inadequate sewage treatment.
• eutrophication and algal bloom.		• explain the effects of eutrophication and algal bloom on marine or aquatic life.
• some water pollutants (e.g. oil and detergent).		• explain the effects of oil and detergent on marine or aquatic life.
• the use of organisms as pollution indicators.	• Show some indicator organisms found in polluted stream. • Discuss the biological principles behind which some organisms can be used as pollution indicators.	• recognise that some organisms can be used as pollution indicators.
	• Use data to review and assess the status of air and water pollution in local environment.	• assess the status of air and water pollution through data analysis interpretation.
	• Read reports from different sources (e.g. newspaper, TV, Internet) on a particular ecological issue.	• develop scepticism towards the reporting of ecological issues by mass media.
	• Ask students to develop action plans to reduce environmental pollution.	• make justified decisions about environmental issues and to develop personal environmental ethics. • formulate action plans to reduce environmental pollution.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
5.2 Human responsibility for environmental conservation		
• the concept of sustainable development and the need for the conservation of natural resources. • afforestation in Hong Kong as a means of restoring degraded or devegetated land. • the management of natural resources (e.g. fish, timber).	• Carry out a project on human responsibility for environmental conservation.	• explain the concept of sustainable development and state its importance. • appreciate the need for the conservation of natural resources. • develop a commitment to live an "environmentally friendly" life.
• the recycling of wastes (e.g. paper, aluminium).	• Search for information on the wastes recycling industry in Hong Kong. • Ask students to cite examples of 4R: reduce, recycle, reuse and replace.	• state the importance of wastes recycling.
• the need to maintain biodiversity: conservation of wildlife and their habitats; ecological, aesthetic and moral considerations.	• Search for information on biodiversity and how it affects the life on Earth. • Visit one conservation area in Hong Kong (e.g. Nature Reserves, Sites of Special Scientific Interest (SSSI), country parks, marine parks, artificial reefs and Ramsar site).	• develop an awareness of the importance of maintaining biodiversity.
• the protection of endangered species in Hong Kong with reference to at least two of the following examples: Chinese White Dolphin, Romer's Tree Frog, Black-faced Spoonbill, and Pitcher-plants.	• Show specimens or pictures of endangered species. • Visit the Endangered Species Resource Centre of Agriculture, Fisheries and Conservation Department.	• appreciate the need to protect endangered species. • suggest ways to protect endangered species. • show respect for life.
• the pollution control measures: sewage treatment, the control of agricultural wastes and industrial effluents.	• Visit a local sewage treatment plant. • Ask students to propose a list of pollutants found in the effluents produced from a number of local industries or those of the Pearl Delta.	• explain how control measures can alleviate environmental problems. • explain the principles of sewage treatment. • explain the need to control agricultural wastes and industrial effluents. • appreciate that science and technology is a double-edged sword in improving or polluting our environment.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the relationship between economic development and conservation of the environment.	• Debate on the dilemma between urbanisation, industrialisation and conservation. • Research on some local examples which illustrate the conflicting interests between economic development and the conservation of the environment. • Create and then role-play a scenario in which a major industry in an area decides to move the factory to Mainland, rather than installing pollution measures which are mandatory and expensive. Roles can include factory owner, workers, spouses or children of the workers, government officials, local residents etc.	• consider various aspects to make logical and rational decisions on environmental issues. • apply problem-solving skills to resolve environmental issues. • appreciate that solutions to environmental problems involve contributions from many subject areas and compromise between different parties.
• the importance of environmental education and legislation.	• Discuss the existing policies on environmental conservation. • Find out the work done and the contribution of a variety of environmentally concerned groups in Hong Kong.	• appreciate the importance of environmental education and legislation.

Section 6 Health and Diseases

Section 6 aims to provide students with an understanding of the biological principles and practices for the promotion of good health and the prevention of some diseases.

This section begins with a discussion on the meaning of health. The effects of diet, exercise, rest and alcohol abuse on health are included with a view to cultivate in students a positive attitude towards a healthy lifestyle. They should also develop a critical mind in applying scientific knowledge to examine lifestyles and habits that affect health. The routes of pathogen transmission and the causes of some non-infectious diseases are to be learnt in association with the biological principles that may lead to their prevention and control. Diseases that are often self-inflicted and avoidable through proper attitudes, good living conditions and healthy lifestyles should be emphasised. The physiological defence mechanisms employed by the human body to combat diseases, the principle of vaccination, the use of antibiotics, and some of their related issues, are also considered.

This section also serves to provide an integration of topics learnt in other sections. For example, *Diet* and health is related to *Nutrition (Section 7)*; *Genetic diseases* and *Some cancers* to *Nuclear division, Mutation, Applications of genetics (Section 3)* and *ozone depletion (Section 5)*; *Cardiovascular diseases* to *Heart* and *Blood vessels (Section 8); Diabetes* to *Regulation of blood glucose level (Section 11)* and *Sexually transmitted diseases* to *Sexual reproduction in mammals (Section 12)*.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
6.1 Some factors affecting health • the meaning of health.	• Brainstorm the meaning of health and compare with the definition of health from World Health Organisation. • List the factors that can affect a person' s health.	• state the meaning of health.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
6.1.1 Diet		
• the importance of balanced diet. • the importance of minerals (calcium, iron and iodine). • the roles of vitamins in enhancing cellular functions (e.g. vitamin B as coenzyme). • the problems of malnutrition, e.g. lack of protein and excessive intake of energy-rich food.	• Discuss the long-term effects of unbalanced diet: fast food diet may or may not be balanced. • Discuss some of the overall consequences of taking improper quantity of a particular dietary component. • Discuss ways in which eating disorders, e.g. anorexia nervosa can affect health. • Investigate the needs and claims of health food supplements.	• point out the general effect on health as a result of prolonged unbalanced diet. • develop a critical attitude towards the quality and quantity of foods consumed. • describe how malnutrition may affect body functions and development. • make informed consumer decisions when selecting and purchasing food.
6.1.2 Exercise and rest		
• the importance of regular exercise and rest on health.	• Ask students to find out the importance of rest and the scientific basis of it. • Search for information on the claim that most of the growth hormone is released during sleep at night, and how enough sleep can affect the growth of adolescents. • Design and perform an investigation to study the aspects of fitness among students.	• point out the importance of regular exercise and rest. • develop an awareness of the effects of different types of exercise in maintaining body fitness.
• the effects of regular exercise on vital capacity, muscle strength, and cardiac output.	• Design and perform an investigation to study the effects of exercise on vital capacity and muscle strength. • Provide data to students and ask them to draw conclusion on the effects of regular exercise on vital capacity, muscle strength and cardiac output, as a measure of fitness. • Ask students to search for information on various types of exercise. Guide them to list out the criteria for choosing suitable exercise and make their own choices.	• state the effects of regular exercise on body functions.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
6.1.3 Alcohol abuse • the general effects of alcoholism.	• Discuss the reasons for control and advice on alcohol consumption, e.g. statutory limit for blood alcohol concentration adopted in drink driving legislation in Hong Kong, recommended weekly consumption limit, minimum age of 18 for purchase of alcohol. • Search for information on the effects of alcohol on body organs and the developing foetus.	• state the effects of alcoholism.
6.2 Transmission of pathogens and prevention of infection • the routes of transmission of pathogens: air (e.g. common cold and influenza), water or food (e.g. cholera), vector (e.g. malaria), body fluids (e.g. hepatitis B, AIDS and sexually transmitted diseases (STDs)). • the biological principles of the prevention and control of transmissible diseases.	• Carry out a project work on disease transmissions. • Discuss the routes of transmission of AIDS and STDs and suggest how the spread of these diseases can be minimised. • Analyse data showing incidence of AIDS in different parts of the world.	• outline the ways by which some transmissible diseases can be spread. • apply biological principles to prevent and control transmissible diseases. • develop an awareness of the personal responsibility in preventing disease transmission.
6.3 Defence against pathogens **6.3.1 Nonspecific defence mechanisms** • the roles of the skin, mucus and other secretions, cilia, blood clotting, phagocytosis and inflammatory response in defence.	• Explore students' prior knowledge on nonspecific defence mechanisms. • Examine features of mammalian skin that are related to body defence using prepared slides or model. • Observe phagocytosis using photomicrographs or audiovisual materials.	• review a variety of nonspecific defence mechanisms.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
6.3.2 Specific defence mechanisms		
• an outline of the humoral and cell-mediated immune responses including an understanding of the terms: antigen, antibody, lymphocytes (B and T cells) and memory cell; primary and secondary responses.	• Ask students to construct flow charts to illustrate how humoral and cell-mediated immune responses work to combat pathogens. • Observe lymphocytes using the prepared slides or photomicrographs.	• define the terms antigen and antibody. • explain the roles of lymphocytes. • describe the humoral and cell-mediated immune responses. • distinguish between primary and secondary responses. • outline the role of memory cells in secondary response.
• the active and passive immunity.		• state the principles and the differences between active and passive immunity.
• the immune response in relation to (1) blood transfusion (ABO blood group and Rh factor), (2) organ transplant.	• Study the process of blood typing using simulated blood or through multimedia resources. • Discuss the ethical and social issues associated with organ transplant.	• describe the immune response associated with blood transfusion and organ transplant. • evaluate the ethical and social aspects associated with organ transplant.
• that allergies are related to over-reaction of immune response as illustrated by asthma.	• Conduct an anonymous survey in class to see if any classmate suffers from any form of allergy. Find out what they are allergic to, the symptoms, and any treatment. • Find out information on the patch test. • Ask students to find out information on asthma (or any form of auto-immune diseases e.g. rheumatoid arthritis, lupus erythematosus).	• develop an awareness that allergy is a kind of immune response.
• AIDS as the impairment of the immune system brought about by HIV.	• Ask students to distinguish between HIV positive and AIDS.	• develop an awareness that AIDS results from impairment of the immune system.
• the principle of vaccination.	• Read how some biologists (e.g. Jenner, Salk, Pasteur) have contributed to the development of vaccinations.	• outline the principle of vaccination.
• the immunisation programmes in Hong Kong.	• Analyse data on the comparison of the incidence of a disease (e.g. Hepatitis B or poliomyelitus) before and after a immunisation programme has been introduced.	• develop an awareness of the importance of immunisation programmes in Hong Kong.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
6.3.3 Use of antibiotics	• Discuss the importance of immunisation programmes in Hong Kong to personal and community health.	
• the use of antibiotics in the treatment of bacterial and fungal diseases.		• define antibiotics. • explain the action of antibiotics, e.g. by killing or inhibiting the growth of bacteria.
• the consequences of the indiscriminate use of antibiotics.	• Find out the effects of the indiscriminate and improper use of antibiotics. • Relate mutation to bacterial resistance.	• apply biological principles to explain the consequences of the indiscriminate use of antibiotics.
6.4 Some non-infectious diseases **6.4.1 Some cancers**		
• cancers as a phenomenon of malignant cell growth.	• Discuss the difference between benign tumour and malignant tumour. • Conduct a project to study the incidences of the various types of cancers in Hong Kong. • List the types of cancers which are increasing and those which are decreasing in Hong Kong and globally.	• explain what cancer is.
• the factors which increase the incidence of cancer: exposure to carcinogens including chemicals, ionising radiations and viruses; hereditary predispositions; and certain lifestyles.	• Search for information and suggest ways to reduce the incidence of certain cancers, e.g. breast, cervical, colon, skin, nasopharyngeal cancer or lung caner. • Design a poster, leaflet or web page advising on ways in which people can reduce their chances of contracting one form of cancer. • Search for information on cancer screening techniques, e.g. smear tests and radiography. • Discuss the role of public education in reducing the risk of cancers.	• give examples of carcinogens. • relate incidence of cancer to exposure to carcinogens. • develop an awareness of certain lifestyles that may increase the incidence of cancers.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
6.4.2 Cardiovascular diseases		
• the factors, e.g. low levels of physical activity, obesity and smoking that increase the incidence of coronary heart disease and stroke.	• Ask students to list out the risk factors of coronary heart disease. • Suggest ways to reduce the incidence of cardiovascular diseases.	• state the factors that increase the incidence of coronary heart disease and stroke.
6.4.3 Diabetes mellitus		
• the insulin-dependent diabetes and non-insulin-dependent diabetes. • the risk factors, e.g. age, persistent overeating of sugary food, obesity, low levels of physical activity, that are associated with non-insulin-dependent diabetes. • the biological principles in the control of diabetes.	• Search for information on the types, symptoms, risk factors, detection, management and control of diabetes.	• point out that there are two forms of diabetes. • state that certain lifestyles are associated with non-insulin-dependent diabetes. • explain the biological principles in the control of diabetes.
6.4.4 Genetic diseases		
• that some diseases are caused by gene defects, e.g. glucose-6-phosphate dehydrogenase deficiency, haemophilia, sickle-cell anaemia. • that some diseases are caused by chromosome mutations, e.g. Down syndrome. [Refer to Section 3.]	• Show photographs displaying the symptoms of some genetic diseases. • Identify chromosome abnormality from photographs showing karyotype.	• give examples of genetic diseases. • state that genetic diseases may have different causes.

Section 7 Nutrition

Organisms may have to acquire and take in all the organic substances they need (heterotrophic nutrition) or synthesise them from simple inorganic raw materials (autotrophic nutrition). This section aims to give students an extended understanding of these modes of nutrition.

Nutrients required by photosynthetic plants in this section complements with *Photosynthesis (Section 2)* to give a full picture of the nutrition of photosynthetic plants. *Holozoic nutrition* is related to *Chemical constituents, Transport of substances in and out of the cell* and *Enzymes* in *Section 1*, and to *Diet* and *Some non-infectious diseases* in *Section 6*. Students should be able to understand the structure-function relationships of different parts of the alimentary canal. Without going into the biochemical details, the important roles of the liver should be emphasised. The characteristic features of saprophytic and parasitic modes of nutrition are also studied as modes of heterotrophic nutrition.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
7.1 Modes of nutrition • autotrophic – photosynthetic and chemosynthetic. [Refer to Section 2.] • heterotrophic – holozoic, saprophytic and parasitic.	• Construct a table to compare the carbon and energy sources of different modes of nutrition.	• distinguish the different modes of nutrition. • relate the different modes of nutrition to nutrient cycling and energy flow in the ecosystem.
7.2 Nutrients required by photosynthetic plants		
• the functions of macronutrients (e.g. nitrogen, phosphorus and magnesium).	• Find out the ingredients of the fertilisers available in supermarkets. • Compare the chemical ingredients of a fertiliser that claims to promote foliage development with one that claims to promote flowering. Figure out the reasoning behind their claims. Design and perform experiments to test the validity of these claims.	• state the functions of some macronutrients in plants.
• that hydroponics is an alternative way of growing plants.	• Conduct a project work on hydroponics.	• appreciate the application of scientific knowledge to agriculture and horticulture.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
7.3 Heterotrophic nutrition		
7.3.1 Holozoic nutrition		
• the general plan of the mammalian alimentary canal and its associated glands (e.g. salivary glands, liver and pancreas); their functions in digestion and absorption.	• Explore students' prior knowledge on the human digestive system. • Dissect a small mammal to examine the general plan of the alimentary canal and its associated glands.	• outline the general plan and state the functions of different parts of the alimentary canal.
7.3.1.1 Ingestion		
• the dentition and dental formulae of a carnivore, a herbivore and an omnivore in relation to diet.	• Examine the skulls of a carnivore, a herbivore and an omnivore to study the dentition in relation to their diets.	• relate the types of diet to the dentition of different mammals.
7.3.1.2 Digestion		
• the digestion of carbohydrates, proteins and lipids in various parts of the alimentary canal. The functions of carbohydrase, amylase, protease and lipase.	• Design and perform experiments to investigate the presence and the activities of protease and amylase in different regions of the gut of a small animal. • Provide students with an appropriate selection of terms related to food and digestion. Ask them to use these terms to make a concept map.	• describe the digestion of carbohydrates, proteins and lipids in different parts of the alimentary canal. • state the conditions under which different enzymes work in different parts of the alimentary canal.
7.3.1.3 Absorption and assimilation		
• the absorption of the products of digestion in ileum. • the routes by which absorbed food substances are transported to the tissues.	• Dissect a small mammal to trace the routes by which absorbed food substances are transported to the heart.	• describe how the products of digestion are absorbed. • describe the routes by which absorbed food substances are transported to the tissues.
• the fates of absorbed food substances.		• describe the fates of absorbed food substances.
• the structure of the ileum wall in relation to its function.	• Examine the structure of ileum under microscope in relation to its digestive and absorptive functions.	• relate the structural features of the ileum to its digestive and absorptive functions.
• the roles of the liver: storage of glycogen, iron and vitamins, breakdown of surplus amino acids and formation of bile.		• describe the roles of the liver in nutrition.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
7.3.2 Saprophytic nutrition		
• the characteristic features of saprophytic nutrition as illustrated in bread mould. • the roles of saprophytes in the ecosystem.	• Examine the features of bread mould using temporary mounts or prepared slides. • Use starch agar plate to demonstrate starch digestion of the bread mould.	• describe the characteristic features of saprophytic nutrition. • explain the roles of saprophytes as decomposers in the nutrient cycles.
7.3.3 Parasitic nutrition		
• the characteristic features of parasitic nutrition as illustrated in tapeworm.	• Examine the features of a tapeworm using prepared slides.	• describe the characteristic features of parasitic nutrition.

Section 8 Gas Exchange and Transport

The role played by oxygen and the subsequent formation of carbon dioxide in cellular respiration is discussed in *Section 2*. This section extends the knowledge above by providing an understanding of how oxygen is brought into, and how carbon dioxide is removed from, the living cells of mammals and flowering plants.

This section also provides continuity with the S4-5 curriculum to expand students' understandings of the structure and function of transport systems in mammals and flowering plants. The control of the rate of heart beat and the oxygen dissociation curves are among some of the important additions. Students should be encouraged to evaluate the evidence for and against the possible mechanisms of transport in flowering plants. The structure-function relationships of different components of the transport systems should be emphasised. Microscopy should be used wherever appropriate.

Prior knowledge of *Cell structure* and *Transport of substances in and out of the cell (Section 1)* lays the foundation for students to understand the processes involved in gas exchange and transport in organisms.

Study of *The circulatory system* should be linked to *Cardiovascular diseases (Section 6)*, and a discussion on the *Control of the rate of heartbeat* should include both *Nervous* and *Hormonal coordination (Section 10).*

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
8.1 Gas exchange		
• the need for a gas exchange system in multicellular organisms.	• Ask students to suggest various ways by which unicellular and multicellular organisms obtain oxygen for respiration. Then ask students why gas exchange system is needed in some multicellular organisms.	• explain the need for a gas exchange system in some multicellular organisms.
8.1.1 Gas exchange in mammals		
• the ventilation mechanism.	• Dissect a small mammal to examine the general plan of breathing system.	• describe how the lungs are ventilated in mammals.
• the effect of carbon dioxide concentration on the rate and depth of breathing.		• state the effects of carbon dioxide concentration on breathing.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the effects of asthma on ventilation. • the exchange of gases at the respiratory surface. • the uptake, transport and release of gases by blood. [Refer to Section 8.2.1.]	• Explore students' prior knowledge on gas exchange.	• develop an awareness of the effects of asthma on ventilation. • explain how air sacs are adapted for gas exchange. • state the roles of blood in gas exchange.
8.1.2 Gas exchange in flowering plants • the roles of stomata and lenticels in a terrestrial flowering plant.	• Examine the stomata and lenticels using temporary mount, prepared slides or photomicrograph. • Measure the stomatal density of leaf specimens using temporary mount.	• describe how gas exchange occurs in terrestrial flowering plants.
8.2 Transport • the need for a transport system in multicellular organisms.	• Ask students to suggest various ways by which multicellular organisms transport oxygen, food and wastes in their bodies. Then ask students why transport system is needed in some multicellular organisms.	• explain the need for a transport system in some multicellular organisms.
8.2.1 Transport in mammals **8.2.1.1 The circulatory system** • the functions of the circulatory system.	• Dissect a small mammal to examine the heart and main blood vessels.	• describe the functions of the circulatory system.
8.2.1.2 Heart • the structure of the heart in relation to its function.	• Dissect a mammalian heart to examine its structures.	• relate the structure of the heart to its function.
• a brief treatment of the cardiac pacemaker and cardiac cycle.	• Search for information on artificial hearts, artificial heart valves, artificial pacemaker and heart transplants. • Use sphygmomanometer to measure blood pressure. • Use a data logger to measure heart rate, and to record and display electrocardiogram (ECG).	• outline the role of cardiac pacemaker in the cardiac cycle. • describe the sequence of events in the cardiac cycle in terms of diastole and systole.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• nervous and hormonal control of the heart rate in relation to changing demands. • the coronary blood supply to heart. Likely causes of coronary heart disease and preventive measures. [Refer to Section 6.4.2.]		• describe the nervous and hormonal control of heart rate. • develop an awareness of the causes of coronary heart disease and preventive measures.
8.2.1.3 Blood vessels		
• the structure of arteries, capillaries and veins in relation to their functions.	• Examine prepared slides of T.S. arteries, capillaries and veins to study their structures. • Make L.P. drawings of blood vessels and make annotations to relate their structures with functions.	• relate the structure of arteries, capillaries and veins to their functions.
8.2.1.4 Blood, tissue fluid and lymph		
• the composition of blood and functions of the following blood cells: red blood cell, blood platelet, phagocytes and lymphocytes.	• Examine prepared slide of mammalian blood smear to study the blood cells.	• relate the composition of blood to its functions.
• the role of blood in the transport of oxygen and carbon dioxide.	• Search for information on the effects of high altitude training for athletes on oxygen carrying capacity of blood.	• state the role of blood.
• oxygen dissociation curves: significance of the Bohr effect.	• Discuss with students the oxygen dissociation curves of different animals.	• interpret the oxygen dissociation curves. • explain the importance of Bohr effect.
• the formation of tissue fluid and lymph and their return to the blood circulatory system. • the roles of tissue fluid and lymph.		• describe the process of tissue fluid and lymph formation. • state the roles of tissue fluid and lymph.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
8.2.2 Transport in flowering plants **8.2.2.1 Vascular tissues**		
• the basic anatomy of vascular tissues in a young root, a young stem, a woody stem and a leaf of dicotyledonous plants.	• Examine the vascular tissues of a young root, a young stem, a woody stem and a leaf of dicotyledonous plants using temporary mounts or prepared slides. • Prepare free-hand sections and temporary mounts of stems, and use simple staining techniques where appropriate. • Make L.P. and H.P. drawings of vascular tissues and cells and make annotations to relate their structures and functions.	• relate the structure of the vascular tissue to transport.
8.2.2.2 Absorption and transport of water and mineral salts		
• the absorption and transport of water: cohesion-tension theory and root pressure.	• Explore students' prior knowledge on transpiration. • Investigate the rate and path of water transport using a dye solution.	• describe the cohesion-tension theory and root pressure, and evaluate their relative importance in the transport of water in plants.
• the pathways of water movement: apoplast, symplast and vacuolar.		• describe the pathways of water movement.
• the absorption of mineral salts by diffusion and active transport; the transport of mineral salts in xylem vessels.		• explain how plants absorb water and mineral salts.
• the structure of guard cells and the distribution of stomata.	• Examine prepared slides of leaf epidermis to study the structure of guard cells and the distribution of stomata.	• relate the structure of guard cells to their functions.
• that transpiration creates water potential gradient within the plant.		• state that transpiration creates water potential gradient within the plant. • describe the movement of water along water potential gradient within the plant.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the factors affecting transpiration.	• Design and perform an investigation to study the effects of the following on the rate of transpiration: (1) air current (2) temperature (3) light (4) humidity	• explain how environmental factors affect transpiration.
8.2.2.3 Transport of organic solutes		
• the evidence for transport of organic solutes in phloem using radioactive tracer and aphids.	• Read about the experiments using radioactive tracer and aphids to study the translocation of organic solutes.	• point out the need for translocation of organic solutes. • evaluate the evidences of phloem transport.
• the translocation of organic solutes in phloem between different regions of the plants (e.g. photosynthetic tissues, storage organs and growth regions).		
• an outline of the mass flow hypothesis of phloem transport.	• Read about the pros and cons of the mass flow hypothesis.	• outline the mass flow hypothesis of phloem transport.

Section 9 Support and Movement

Section 9 aims to study the structures and mechanisms involved in the support and movement of plants and selected animals, both on land and in water. Wherever possible, this section should be dealt with by relating structure to function.

The structural adaptations of organisms to support and movement can best be substantiated by first-hand observations in the field *(Variety of life, Section 4).* Movement in animals should be viewed as the result of the arrangement, interaction and coordination of the nervous, muscular and skeletal systems. The mechanism of muscle contraction should include its initiation by nerve impulse *(Section 10)* and an understanding of the sliding-filament hypothesis. Studies on the cell structure of supporting tissues (parenchyma, collenchyma, sclerenchyma and xylem, *Section 1*) contribute towards the understanding of support in plants. Phototropism and geotropism should be understood as a kind of growth movement in response to external stimuli *(Section 10).*

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
9.1 Support in animals		
• the general plan of the mammalian skeleton and an outline of its functions, including serving as a calcium reservoir.	• Examine a mammalian skeleton to study how its structure is related to its functions in support, movement and protection.	• outline the general plan and state functions of a mammalian skeleton.
• the structure of a long bone.	• Show photographs or specimens of longitudinal section of a long bone. • Search for information about osteoporosis. Suggest who is most likely to be at risk and why. • Search for information on the ways to minimise osteoporosis, its possible cures.	• relate the various parts of a long bone to its mechanical function.
• the role of muscles in maintaining posture, with mentioning of muscle tone.	• Search for information about the importance of good postures, and discuss in class.	• point out that muscles contribute to maintaining body posture. • develop an awareness of the habitual bad postures in our everyday life.
• the different means of support of aquatic and terrestrial animals as exemplified by a bony fish and a terrestrial tetrapedal mammal.	• Examine the skeletons of a bony fish and a terrestrial tetrapedal mammal, noting their adaptations related to support.	• compare the means of support of aquatic and terrestrial animals.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
9.2 Movement in animals		
• stability, support and propulsion as exemplified by swimming in a bony fish and walking in a tetrapedal mammal.	• Use audiovisual materials to show the forms of locomotion in a bony fish and a tetrapedal mammal.	• outline the mechanisms involved in the movement of selected animals, and relate the mechanisms to their adaptations to live on land or in water.
• the initiation of muscle contraction by nerve impulses. [Refer to Section 10.2.1.]	• Observe the contraction of a teased muscle from the leg of a pithed frog by electrical stimulation.	• describe how a nerve impulse transmits across the neuromuscular junction leading to muscle contraction.
• the sliding-filament hypothesis of muscle contraction without mentioning the ratchet mechanism and the excitation-contraction coupling mechanism.	• Examine the electron micrograph of a skeletal muscle fibre. • Use audiovisual materials to illustrate the sliding-filament hypothesis of muscle contraction.	• use the sliding-filament hypothesis to explain muscle contraction. • appreciate the use of a model to explain a biological phenomenon.
• the structure of a synovial joint.	• Use models or audiovisual materials to show the structure of a synovial joint.	• relate various parts of a synovial joint to their functions.
• the role of joints and muscles in locomotion.	• Construct models or use an articulated skeleton to demonstrate how muscles move appendages such as the leg. • Use audiovisual materials to show the movement at a synovial joint.	• describe the role of joints and muscles in locomotion. • appreciate the complex coordination of skeleton, joints and muscles in locomotion.
9.3 Support in plants		
• the turgidity of cells; types and distribution of supporting tissues in young and woody dicotyledonous plants. [Refer to Section 12.2.3.]	• Examine the types and distribution of supporting tissues in young and woody dicotyledonous stem using microscope. [Refer to Sections 1.2, 8.2 and 12.2.]	• identify different types of supporting tissues and relate their special features to their functions. • compare the nature of support in herbaceous plants and in woody plants.
• the different means of support in terrestrial and aquatic plants.	• Examine the T.S. stem and leaf of an aquatic plant using microscope, and compare their anatomy with that of a terrestrial dicotyledonous plant.	• compare the means of support in aquatic and terrestrial plants.
9.4 Movement in plants		
• the significance of phototropism and geotropism. [Refer to Section 10.4 and 12.2.4.]	• Explore students' prior knowledge on the significance of phototropism and geotropism in plant.	• explain the significance of phototropism and geotropism to the survival of plant.

Section 10 Sensitivity, Response and Coordination

To survive, an organism must be able to respond to changes in its external and internal environments. This necessitates having mechanisms for detecting such changes and producing appropriate responses.

How sense organs detect environmental stimuli and pass the sensation into the nervous system is discussed with particular reference to the mammalian skin, eye and ear. The communicative roles played by the nervous and hormonal systems in bringing about appropriate responses for the well being of the animal should be discussed. This section closes with the response of flowering plants to the environment and the roles of phytohormones in regulating growth, differentiation and various tropisms.

Studies on the transmission of nerve impulse should also be linked to the *Initiation of muscle contractions (Section 9).* Knowledge of hormonal coordination prepares students for an understanding of the actions of hormones in *Homeostasis (Section 11)*, and the *Control of the menstrual cycle, Growth and Development (Section 12).*

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
10.1 Detection of environmental conditions in mammals **10.1.1 The skin**		
• that the skin can detect various external stimuli.	• Carry out an investigation on the detection of external stimuli by the skin.	• state the sensory functions of the skin.
10.1.2 The eye		
• the mechanism of vision: functions of rods and cones, colour vision, visual sensitivity and visual acuity.	• Explore students' prior knowledge on the structure of the eye. • Dissect a mammalian eye to study its structure.	• state and compare the functions of rods and cones. • explain the mechanism of colour vision. • compare the visual sensitivity and acuity of the rods and cones.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
10.1.3 The ear • the structure of the ear. • the mechanism of hearing: the role of the organ of Corti, perception of sounds of different pitches and intensities.	• Use model or audiovisual materials to show the structure of the ear. • Use audiovisual materials / prepared slides / photomicrographs to show the structure of the organ of Corti. • Ask students what they know about the hearing range of different mammals. Discuss how human can communicate with dogs using whistles. • Ask student to discuss how different mammals use sound, e.g. long-distance communication in whales, ultrasonic echo location in bats.	• explain the roles of various parts of the ear in hearing.
• the role of sacculus and utriculus in detecting the position of the head. • the role of ampulla in detecting the direction of head movement and rate of change of the position of the head.	• Use audiovisual materials / prepared slides / photomicrographs to show the structure of the ampulla. • Use model or audiovisual materials to show the functioning of the sacculus, utriculus and ampulla. • Ask students to design and perform an investigation to find out whether hearing range decreases with age.	• explain the roles of various parts of the ear in detecting of body movement and posture.
10.2 Nervous coordination in mammals **10.2.1 Neurone and transmission of nerve impulse**		
• the structure and functions of different types of neurones. • nerve impulse: generation and transmission of nerve impulse; the role of Na^+ and K^+ ions; production of resting and action potentials; all-or-nothing nature of the action potential; concept of threshold without mentioning the refractory period.	• Examine prepared slides or electron micrographs of neurone to study its typical structures. • Use audiovisual materials to show the conduction of nerve impulse.	• state the structure and functions of the neurones. • state that the neurone is a highly specialised cell type. • state the nature of nerve impulse. • describe the mechanism of generation and conduction of nerve impulse.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the factors affecting the rate of transmission of nerve impulses.		• list the factors affecting the rate of transmission of nerve impulses. • explain the factors affecting the rate of transmission of nerve impulses.
• the synaptic transmission between neurones and at neuromuscular junction without mentioning the role of calcium, spatial summation and temporal summation. [Refer to Section 9.]	• Examine an electron micrograph of a synapse to study its structure. • Use audiovisual materials to show the chemical transmission at the synapse. • Ask students to search for information on how drugs affect the functioning of the synapses. • Ask students to discuss the biological principle of nerve gas as biochemical weapon.	• describe the mechanism of synaptic transmission.
10.2.2 Central nervous system		
• the organisation of the nervous system into the central nervous system and the peripheral nervous system.		• develop an appreciation of the complex organisation of the nervous system.
• the gross structure of the human brain.	• Use model to illustrate the gross structure of the human brain. • Use model or diagram to illustrate the median vertical section of the human brain.	• identify the various parts of the human brain.
• the structure of the spinal cord. • the functions of the cerebrum, hypothalamus, cerebellum, medulla and spinal cord.	• Examine prepared slide of T.S. mammalian spinal cord.	• identify the various parts of the spinal cord. • state the functions of various parts of the central nervous system.
10.2.3 Autonomic nervous system		
• the control of involuntary activities by the sympathetic and parasympathetic nervous systems with reference to their antagonistic actions.		• state the role of the autonomous nervous system. • describe the antagonistic actions of the sympathetic and parasympathetic nervous systems.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
10.2.4 Reflex action and voluntary action • the functioning of a spinal reflex and the types of neurones involved. • the significance of spinal and cranial reflexes. • about the different nature of conditioned reflex and voluntary action.	• Search for information on the significance of various reflexes, and their adaptive values, in a newborn. • Discuss the importance of reflex action, conditioned reflex and voluntary action in everyday life.	• explain the functioning of a spinal reflex and the types of neurones involved. • state the significance of spinal and cranial reflexes. • cite examples of reflex action, conditional reflex and voluntary action. • compare the nature of reflex action, conditioned reflex and voluntary action. • outline the importance of reflex action, conditioned reflex and voluntary action in everyday life.
10.3 Hormonal coordination in mammals • the nature of hormonal coordination. • the differences between nervous and hormonal coordination. • the control of endocrine activity: (1) the nervous system (e.g. adrenaline secretion under stress, oxytocin secretion in lactation); (2) the concentration of hormones (e.g. hormonal control in menstrual cycle [Refer to Section 12.1.2.1]; and the negative feedback mechanism in thyroxine secretion); and (3) other substances in the blood (e.g. the effects of blood glucose level on insulin and glucagon secretion).	• Use any hormone (e.g. insulin) as an example to illustrate the action and characteristics of hormonal coordination. • Use flow charts to illustrate the various control mechanisms of endocrine activity.	• describe the nature of hormonal coordination. • compare the nature of nervous coordination and hormonal coordination. • explain the difference between the nature of nervous coordination and hormonal coordination. • describe the different mechanisms that control endocrine activity. • relate the principle of negative feedback mechanism to homeostasis.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
10.4 Response to the environment in flowering plants		
10.4.1 Tropism		
• the responses of shoots to light and gravity; the responses of roots to gravity and water, including the role of auxins in phototropism and geotropism. [Refer to Section 9.4.]	• Conduct demonstrations of geotropism and phototropism to show the region of perception and region of response.	• state the regions of perception to light and gravity, and explain the growth responses in terms of auxins.
• the experimental evidence on the region of perception and region of response in phototropism and geotropism.	• Study the experiments performed by Darwin, Boysen-Jensen and Went on coleoptiles.	• evaluate the design and conclusions of experiments that lead to the formulation of a mechanism for tropic movements in flowering plants.
10.4.2 Photoperiodism		
• the types of photoperiodic responses in flowering. • the significance of photoperiodism in control of flowering.	• Search for information on examples of long-day plant, short-day plant and day-neutral plant.	• describe the phenomenon of photoperiodism in flowering. • develop an awareness of the commercial applications and implications of photoperiodism in the control of flowering.
10.4.3 Phytohormones		
• phytohormones as biological substances to regulate growth and differentiation, e.g. auxins, gibberellins and ethylene (ethene).		• state the roles of phytohormones in regulating growth, differentiation and various tropisms.
• the applications of phytohormones in agriculture and horticulture.	• Search for information on the applications of phytohormones.	• suggest how phytohormones can be used in agriculture and horticulture.

Section 11 Homeostasis

Life processes can only take place within quite a narrow range of physical and chemical conditions. For a multicellular organism to survive, the conditions of the internal environment surrounding its cells must be maintained within narrow limits. Any deviation from these limits may be fatal, unless quickly corrected.

This section aims to provide students with an extended understanding of the homeostatic mechanisms involved in the regulation of water balance, body temperature and blood glucose level. It also illustrates how the various body systems work together to regulate the internal environment for the best functioning of the animal. Water balance in terrestrial flowering plants should be discussed with particular reference to the adaptations shown by xerophytes.

Prior knowledge of *Hormonal coordination in mammals (Section 10)* provides a foundation to the understanding of the actions of hormones in homeostasis. Faulty regulation of blood glucose level is a subject discussed under *Diabetes (Section 6).*

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
11.1 Homeostasis • the need for the regulation of the internal environment and the concept of negative feedback.	• Discuss why organs donated for transplantation should be kept in ice-cold saline solution.	• point out the importance of a constant internal environment and the negative feedback mechanism involved in its maintenance. • develop an appreciation of the interrelationships of various systems in maintaining a constant internal environment.
11.2 Water balance • the structure and functions of the mammalian kidney. • the formation of urine as a result of ultrafiltration, reabsorption of solutes and water including the role of loop of Henle, and tubular secretion.		• relate the structure of the kidney to its functioning in regulation of water.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the action of antidiuretic hormone (ADH). • the biological principle of the dialysis machine (kidney machine).	• Use audiovisual materials to show the structure of a dialysis machine, and discuss with students the scientific principles involved. • Discuss alternative ways to dialysis machine, e.g. peritoneal dialysis, kidney transplant. • Suggest a diet for patients with renal problems with reasons.	• describe the effects of ADH. • state the biological principle involved in dialysis machine.
• water balance in terrestrial flowering plants including adaptations shown by xerophytes.	• Examine the structural adaptive features of xerophytes in relation to water balance.	• relate water balance in terrestrial flowering plants including xerophytes to their adaptations.
11.3 Regulation of body temperature		
• the importance of body temperature regulation. • the meaning of ectotherms and endotherms. • the role of the skin, circulation, muscles, hypothalamus, nervous system, and hormones (adrenaline and thyroxine) in the regulation of body temperature. • the physical and metabolic methods in the regulation of body temperature.	• Examine the features of mammalian skin in relation to temperature regulation. • Discuss how ectotherms and endotherms respond to hot and cold conditions. • Construct a concept map to show the mechanism of temperature regulation.	• point out the importance of the body temperature regulation in metabolic activities, behaviour and ecological distribution of animals. • distinguish between ectotherm and endotherm. • describe how ectotherms and endotherms respond to hot and cold conditions. • state the mechanism of temperature regulation in mammals. • apply the negative feedback mechanism to explain the homeostatic control of body temperature.
11.4 Regulation of blood glucose level		
• the action of pancreatic hormones on blood glucose regulation. [Refer to Section 6 and 10.] • the role of liver in blood glucose regulation.	• Construct a concept map to show the mechanism of blood glucose regulation.	• point out the importance of maintaining constant blood glucose level. • explain the role of insulin and glucagon in blood glucose level regulation. • apply the negative feedback mechanism to explain the homeostatic control of blood glucose level.

Section 12 Continuity of life, Growth and Development

All living organisms have a finite life span, the continuity of each species depends on the ability of individual organisms to reproduce. Reproduction, whether asexual or sexual, determines the extent of variation from one generation to the next and is accompanied by growth and development.

This section builds on the S4-5 curriculum and aims to extend students' understanding of reproduction, growth and development in mammals and flowering plants. In *Asexual reproduction (Section 12.1.1)*, various modes of asexual reproduction are reviewed, the idea of tissue culture in plants and the cloning in mammals is also introduced. The processes associated with *Sexual reproduction in mammals (Section 12.1.2.1)* are included with a view to understand the various methods of birth control in humans. The intimate relationships of sex hormones, uterine wall development and ovarian changes in the menstrual cycle should be studied and applied to explain how hormones can be used as contraceptives and in treating infertility. *Sexual reproduction in flowering plants (Section 12.1.2.2)* includes seed germination and its physiological changes. This section closes with a discussion on the growth and development in mammals and flowering plants.

To appreciate how organisms reproduce, it is necessary to understand how cells divide *(Cell cycle, Section 3)*. The applications of cloning have been covered in *Plant and animal breeding (Section 3)*. Prior knowledge of *Hormonal coordination in mammals (Section 10)* provides a foundation to the understanding of hormonal control on menstrual cycle, lactation, growth, and development in mammals. Knowledge of sexual reproduction in mammals leads to a better understanding of *Sexually transmitted diseases (Section 6)*. Some of the topics covered here complement and provide the background for a consideration of human sexuality and family planning which is part of the sex education programme in schools (Refer to Guidelines on Sex Education in Schools).

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
12.1 Reproduction		
• the significance of asexual and sexual reproduction.		• state the significance of reproduction. • compare the advantages and disadvantages of asexual and sexual reproduction.
12.1.1 Asexual reproduction		
• the various modes of asexual reproduction, e.g. binary fission, budding, spore formation and natural vegetative propagation of flowering plants.	• Use prepared slides or photomicrographs to show various modes of asexual reproduction, e.g. binary fission, budding and spore formation.	• develop an awareness of the various modes of asexual reproduction. • relate the concept of asexual reproduction with the process of mitosis.
• the application of artificial vegetative propagation in horticulture.	• Examine a range of stem, root and leaf propagules in flowering plants. • Grow new plants from propagules. • Visit a local farm or nursery to gather information with respect to the artificial propagation of house plants or fruit trees.	• appreciate the application of artificial vegetative propagation (cutting and grafting) in horticulture, such as the production of new variety of plants or fruits.
• that tissue culture is a means of cloning plants.	• Use audiovisual materials to show the process of tissue culture and cloning.	• state the advantages and applications of tissue culture in plants.
• about cloning in mammals and its ethical implications.	• Collect newspaper cutting on cloning of mammals. • Debate on the ethical issues related to the cloning of mammals.	• develop an awareness of the advantages and applications of cloning in mammals. • evaluate critically the controversies of cloning with respect to its ethical implications.
12.1.2 Sexual reproduction		
12.1.2.1 Sexual reproduction in mammals		
• the function of various parts of the male and female reproductive systems.	• Dissect a small mammal to examine the urinogenital system. • Examine sections of mammalian testis and ovary to study their simple histology.	• state the functions of the various parts of the male and female reproductive system.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the menstrual cycle in humans and its hormonal control.	• Interpret a graph showing the fluctuation of hormones and the changes of the uterine lining of the menstrual cycle.	• describe the interaction of hormones in the menstrual cycle.
• the use of hormones as contraceptives and in treating infertility in humans.	• Study the ingredient label of the package of contraceptive pills. • Conduct a project work on various ways in which infertility can be dealt with.	• explain how hormones can be used as contraceptives and for the treatment of infertility.
• the significance of courtship behaviour.	• Use audiovisual materials to show the courtship behaviour of some mammals. • Discuss the significance of such behaviour.	• develop an awareness of the significance of courtship behaviour in reproduction.
• about the relative size and relative mobility of sperms and eggs.	• Examine photomicrographs of sperm and egg.	• compare the size and the mobility of sperms and eggs.
• an outline of the process of fertilisation and the significance of internal fertilisation.	• Use audiovisual materials to show the process of fertilisation.	• outline the process of fertilisation and the significance of internal fertilisation.
• the foetus and the newborn: • implantation.		• state the significance of implantation.
• nutrition, gas exchange and excretion of the foetus in relation to the placenta.	• Discuss how specific substances (e.g. food, nicotine, alcohol, drugs, antibiotics etc.) taken into the body of a pregnant woman may affect her foetus. • Outline the general route taken by nutrients from the mother's digestive system to the foetus's brain.	• describe the nutrition, gas exchange and excretion of the foetus in relation to the placenta.
• the process of birth, lactation [refer to Section 10] and parental care.	• Discuss the advantages of breast-feeding.	• describe the process of birth. • describe the hormonal and nervous control of lactation. • point out the significance of parental care.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
• the various methods of birth control in humans with the processes associated with sexual reproduction. [Refer to Guidelines on Sex Education in Schools.] • the biological principles underlying the various methods of birth control.	• Conduct a project work on the pros and cons of various methods of birth control.	• describe the methods of birth control in humans. • explain the biological principles underlying the various methods of birth control. • assess the effectiveness and limitations of these methods. • relate birth control to human population increase and population pressure on the environment.
12.1.2.2 Sexual reproduction in flowering plants		
• the floral parts and their functions.	• Dissect a flower to examine the individual floral parts. • Examine the photomicrograph of the T.S. of an anther or a pollen sac.	• relate the floral parts of a flower to their functions in reproduction.
• the occurrence of self-pollination and cross-pollination. • the advantages and disadvantages of self-pollination and cross-pollination.		• distinguish between self-pollination and cross-pollination. • compare the significance of self-pollination and cross-pollination.
• the growth of pollen tube and double fertilisation leading to the formation of embryo and endosperm. • the fate of floral parts after fertilisation.	• Observe the growth of the pollen tube in sugar solution.	• outline the process of fertilisation, seed and fruits formation.
• the structure and function of different parts of a dicotyledonous seed and a monocotyledonous seed.	• Examine the gross and internal structure of seeds, e.g. broad bean, mung bean and maize.	• relate the different parts of a dicotyledonous seed and a monocotyledonous seed and their functions associated with sexual reproduction.
• the significance of dispersal of fruits and seeds.	• Examine a range of fruits and seeds to study the features related to dispersal.	• state the significance of dispersal of fruits and seeds.
• an outline of the physiological changes during seed germination. • the importance of dormancy in seeds.	• Investigate the enzyme activities at the onset of germination. • Ask students to list out factors (e.g. environmental factors, presence of inhibitory substances) that may prevent seed germination. • Ask students to study the instructions or labels of some seed packages.	• outline the physiological changes during seed germination. • explain the meaning of seed dormancy. • discuss the significance of seed dormancy.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
12.2Growth and development		
12.2.1 Measurement of growth		
• the parameters of growth. • growth curves.	• Use different parameters of growth to take measurements and use the obtained data to plot growth curves.	• critically assess the various parameters to measure growth and state their limitations.
12.2.2 Metamorphosis		
• metamorphosis as illustrated by mosquitoes.	• Use audiovisual materials to show the life cycle of mosquito.	• relate the significance of metamorphosis to reproduction and survival.
12.2.3 Primary growth and secondary growth in flowering plants		
• cell division, enlargement and differentiation.	• Examine prepared slides of root tips to identify the different regions of growth.	• distinguish between growth and development in flowering plants.
• the functions of apical and lateral meristems.	• Examine prepared slides of dicotyledonous stems and roots to identify the location of apical and lateral meristems. • Examine prepared slides of cross sections of the young and old stems of dicotyledonous plants.	• describe the distribution of meristems in dicotyledonous plants and their roles in growth.
12.2.4 The control of growth and development		
• the control of growth and development by hormones: (1) the roles of auxins and gibberellins in shoot elongation and germination, and the role of ethylene (ethene) in fruit ripening in flowering plants [Refer to Section 10.]	• Investigate the conditions which may affect the rate of ripening in fruits. • Show photographs of the effect of gibberellins on the promotion of shoot growth. • Show specimens of plantlets (e.g. orchid) grown from tissue culture.	• outline the effects of various hormones on the control of growth and development in flowering plants and mammals. • appreciate the applications of plant hormones on agriculture, horticulture and storage of fruits.

Learning objectives *Students should learn*	**Possible learning and teaching activities**	**Expected learning outcomes** *Students should be able to*
(2) growth hormone, thyroxine and sex hormones (secondary sexual characteristics) in mammals.	• Discuss how hormones have been exploited by farmers to increase the milk production and the meat production of livestock, and by certain over-ambitious athletes to improve their performance. • Ask students to find information on some transsexuals who may make use of sex hormones.	• state the effects of hormones on mammalian growth.
• other factors controlling human growth and development, e.g. nutritional effects, genetic effects and effects of exercise.	• Ask students to search for information on the factors controlling human growth and development. Guide them to discuss the factors leading to the differences in human growth and development.	• explain how other factors affect human growth.

Section 13 Practical work

Practical work is an indispensable part of this curriculum, as Biology is a science based on experimentations and critical observations. Students are required to engage in practical work for the development of a set of scientific process skills listed in p.3 of this Guide for studying biological phenomena. Practical work can also stimulate students' interest and provide enjoyment in the study of organisms and living processes, and help students develop the values and attitudes listed in p.3 of this Guide. In this way, practical work can contribute towards the personal growth and development of students, which is an essential aim of this curriculum.

In light of the open and flexible nature of this curriculum, teachers should exercise their professional judgement to arrange suitable practical work to help students achieve the scientific process skills, attitudes and values where they think fit. **Teachers should refer to the *Learning objectives* and *Possible learning and teaching activities* in Sections 1 - 12 to select suitable practical experiences, or to design their own.**

The following table shows a range of learning objectives that are required in this curriculum, and some examples of practical work in achieving the expected learning outcomes:

Learning objectives *Students should learn to*	**Examples of possible practical work** *(Please refer to the possible learning and teaching activities of each section for other suggestions.)*	**Expected learning outcomes** *Students should be able to*
• make observations with the naked eye.	• Study organisms (e.g. algae, ferns, gymnosperms, angiosperms including monocotyledonous plants and dicotyledonous plants, molluscs, annelids, echinoderms, cnidarians, arthropods, vertebrates) in relation to their natural habitats during field studies.	• observe critically with the naked eye for features of biological interest. • develop an objective attitude towards evidence. • respect for life and environment.
• display biological specimens and structures.	• Display a dissected flower to show an understanding of the arrangement of floral parts. • Display a dissected small mammal to trace the routes by which digested materials are transported to the heart.	• display biological specimens and structures properly. • appreciate the intricate arrangement of organ parts and organ relationships in biological systems.

Learning objectives *Students should learn to*	**Examples of possible practical work** *(Please refer to the possible learning and teaching activities of each section for other suggestions.)*	**Expected learning outcomes** *Students should be able to*
• make biological drawing.	• Make L.P. drawings of sections of blood vessels and make annotations to relate their structures with functions. • Make L.P. and H.P. drawings of the vascular tissues and associated cell types and make annotations with reference to their functions. • Make whole specimen drawings of a variety of organisms to show structures in relation to adaptation.	• make accurate biological drawing. • label biological drawing properly to show an understanding of the observable features. • make suitable annotations on drawings. • develop an awareness of recording observations honestly.
• carry out free-hand sectioning, staining and mounting techniques for microscopic investigation and examination.	• Prepare free-hand sections and temporary mounts of dicotyledonous stems, and use simple staining techniques to show the layout of supporting tissues. • Prepare temporary mounts of leaf epidermis (e.g. onion, *Zebrina* sp., *Rhoeo discolor*) to study plasmolysis or to record stomatal density.	• carry out free-hand sectioning, staining and mounting techniques properly in the preparation of temporary slides. • develop an awareness of the need for appropriate safety measures.
• use light microscope in making observations.	• Make low-power observations to examine the structure of ileum in relation to its digestive and absorptive functions. • Make high-power observations of vascular tissues and cells and make annotations to relate their functions.	• set up and use a light microscope properly in making observations. • develop an awareness of the reliance of technology in collecting evidence or making observations in the study of biology.
• design and perform investigation to study biological phenomena and processes, and to test hypotheses.	• Guide students to design investigations to study the effects of different factors on the rate of enzymatic reactions. • Investigate the rate and path of water transport using a dye solution.	• design and perform experiments and investigations to study biological phenomena and processes, and to test hypotheses. • develop an awareness of the need for experimentation to collect evidence in support of a formulated hypothesis or to find out the contrary. • develop an objective attitude towards evidence. • develop patience and care. • develop an awareness of the need for appropriate safety measures. • develop a critical and enquiring mind.
• carry out dissection.	• Dissect a small mammal to examine the general plan of the alimentary canal and its associated glands. • Dissect a mammalian heart to examine its structures. • Dissect a flower to examine the individual floral parts.	• demonstrate good manipulative skills. • use dissecting instruments properly. • display structures clearly.

Learning objectives *Students should learn to*	**Examples of possible practical work** *(Please refer to the possible learning and teaching activities of each section for other suggestions.)*	**Expected learning outcomes** *Students should be able to*
• conduct ecological field study.	• Study the distribution of lichens on a tree trunk or boulder. • Conduct an ecological study of a local habitat to measure the physical factors of the environment, and to find out the distribution of plants and animals using appropriate sampling methods in the field.	• plan and perform ecological field studies. • use appropriate instruments to measure the physical parameters of the environments properly. • use appropriate sampling methods in collecting biological data in the field. • collaborate with others. • develop an interest in studying living organisms and their interrelationships. • respect life and the environment while carrying out ecological field studies. • develop an awareness of the need for appropriate safety measures in ecological field studies.

The nurturing of scientific process skills requires a carefully designed plan of implementation to couple suitable practical activities with progress of students' understanding for an integrated approach to foster understanding.

The **Teacher Assessment Scheme (TAS)** requires school teachers to assess practical work of their own students and report the results of such assessments to the Hong Kong Examinations Authority for recognition of students' achievements in the examination. This scheme is an integral part of the A-Level Biology curriculum. When carrying out the TAS, teachers should consider the following:

1. TAS is a continuous process, therefore the teaching programme or scheme of work should include assessment of practical work to evaluate the skills and attitudes developed by the students. Assessment in TAS should arise naturally from coursework activities rather than a series of practical tests solely for the TAS. Hence, teachers are encouraged to provide rich and diverse practical experiences to their students, so that they can develop a full range of practical skills, abilities, values and attitudes to meet the aims and objectives of this curriculum.

2. Experiences in rat dissection and in field work are also required in the TAS. Although the assessment in these two aspects are not

compulsory, teachers could choose them for assessment purpose. In the light of assessment for learning, a criteria checklist designed by the teachers in accordance to TAS requirements may help to evaluate the students and to provide feedback for improvement. The TAS requires students to demonstrate their abilities in the following:

- to carry out practical work,
- to design and perform experiments (a detailed description will be discussed in the following paragraph),
- to report experimental findings, and
- to make annotated biological drawings.

Attention should be drawn to the development of abilities or attributes involved in practical work, such as the manipulative skills, organisation of bench work, process of scientific investigations, creativity, and problem-solving.

3. The TAS puts a heavy emphasis on students' performance in **scientific investigations.** In such connection, students should be evaluated on their ability to design and perform an investigation. This involves:

- the identification of the problem for investigation,
- the deliberation of the principles employed in the design,
- the selection of appropriate methods to carry out the investigation,
- the organisation of the investigation,
- the selection of appropriate apparatus and materials to carry out the investigation, and
- the proper handling of equipment with due attention paid to safety.

The quality of presentation of experimental findings, the ability to interpret, discuss and draw conclusions based on the findings are also aspects to be assessed. Teachers should note that where appropriate, opportunities should be provided to students to practise the formulation of hypothesis, followed by its testing. It is hoped that through engaging in the scientific process itself, students will appreciate the nature of scientific investigations.

4. For details of assessment criteria regarding the practical skills and abilities with regard to the above, teachers are requested to refer to the TAS Handbook.

III. LEARNING AND TEACHING

Learning is a process of an individual' s acquisition and construction of knowledge, as well as co-participation in cultural practices by which knowledge is created. Active participation in various kinds of learning activities foster construction of meanings by the learners. The effectiveness of learning does not solely depend on teaching methods. Teaching activities are equally important. Learning and teaching are interactive processes; they involve complex and dynamic relationships between the individual learner, the teacher, and the learning context. By adopting appropriate teaching approaches and strategies in suitable learning contexts, with clear goals and expectations of learning, learners will be motivated to take an active role in the learning processes.

Students should be placed at the centre of learning. As active learners; students should initiate, organise, make decisions on and take responsibility for their learning. To foster the ownership of learning, students need to be guided to, and engaged in setting goals, developing their criteria of assessment and evaluating their learning progress. The feeling of ownership generates enthusiasm. When students start to believe in themselves, confidence grows. This in turn breeds positive feelings and motivation, resulting in effective learning. Collaborative learning that allows students to contribute various ideas at different levels should be encouraged. Learning from peers and collaboration provides the emotional basis to boost motivation and learning. Skills and habits developed in this active learning process are essential for students to become life-long learners.

Teachers should be well acquainted with the aims and objectives of the biology curriculum and plan meaningful learning activities for their fulfilment. Teachers play various roles in the learning and teaching processes, from a transmitter of knowledge to resource person, facilitator, consultant, counsellor, and assessor. They should employ a variety of teaching approaches and strategies to achieve the different purposes of learning. Teachers should motivate students through a variety of ways, such as sharing with them the learning intentions, encouraging the involvement of students in the learning and teaching processes, considering their emotional reactions, meeting their interests, and building learning and teaching on their successful experiences.

Use of learning and teaching resources

A diversity of learning and teaching resources should be used to enhance the effectiveness of learning. Life-wide learning opportunities should be provided to widen the exposure of students to the scientific world. Examples of learning programmes include popular science lectures, debates and forums, issue-based learning, co-curricular activities, field studies, museum visits, invention activities, science competitions, projects and exhibitions. Community resources, e.g. field studies centres, country and marine parks, education centres at Island House and Mai Po, government departments like the Environmental Protection Department, the Agriculture, Fisheries and Conservation Department, can provide life-wide learning contexts and rich learning resources to facilitate learning and to complement self-learning. Students with higher abilities or a strong interest in science may need more challenging learning experiences which can stretch their science capabilities and offer opportunities for them to reach the fullest potential.

The judicious use of audiovisual materials lets students experience a world beyond the school and give visual realisations of abstract ideas and concepts. Many videotaped science programmes provide good teaching materials and help students keep abreast of the latest scientific and technological developments. Teachers are encouraged to bring these programmes to the attention of their students, and follow up with discussions that help them relate these to the curriculum and make learning more relevant and interesting. Newspaper articles are good resource materials. Newspaper cuttings on topics of interests such as soil erosion, desertification, and Human Genome Project, can be put on display for general information. Students can be given projects to collect articles relevant to the topic as an extension of learning.

Information technology for interactive learning

Information technology for interactive learning complements strategies of learning inside and outside the classroom. Computers can be used to support scientific investigations, e.g. data loggers can be used for data acquisition and analysis in biology experiments, indoor and outdoor. Students can also create data tables, process the data, plot the results, and find out mathematical relationships, e.g. in measuring the growth rate of plants, monitoring oxygen consumption of animals. Computer programmes may be used to simulate animal dissections, laboratory experiments or environmental scenarios, e.g. the process of natural selection could be simulated by using appropriate software. The Internet is a particularly valuable source of scientific information and resources that facilitates student learning. The Internet can

provide opportunities for students to learn, sometimes collaboratively with students in another part of the world. The use of information technology in learning allows students to work at their own pace, and gives them more time to pursue creative activities in biology, as well as to experience enjoyment through biology-related games or programmes.

Contextual approach

When the study of biology is related to students' everyday life, it will be more relevant and meaningful to them. Therefore, where possible, teachers should adopt a contextual approach which helps students integrate their learning of biological concepts, skills and attitudes in a technological or social context. Teachers could introduce biology topics from areas of contact with students' lives, thus enhances students' motivation to inquire, apply and reflect on what they have learned. Through a systematic inquiry as guided by teachers, students should be able to acquire, in a step-wise manner, the relevant concepts, skills and attitudes. To maximise learning effectiveness, both the learning contexts and inquiry activities should be built upon the existing knowledge, ideas and experiences of the students.

Example:
In Section 5, Human Activities and the Environment, students are suggested to visit one of the conservation areas in Hong Kong, e.g. Nature Reserves, Sites of Special Scientific Interest (SSSI), country parks, marine parks, artificial reefs or the Ramsar site. This activity could be used as a starting point for students to explore the different kinds of wildlife being endangered in the local habitats, e.g. Chinese White Dolphins, Romer's Tree Frogs, and various types of corals, and why there is a need to maintain biodiversity including ecological, aesthetic and ethical considerations.

Historical approach

Biology, as well as other disciplines of science, is built upon the combined efforts and the accumulated wisdom of scientists through scientific processes. Incorporating the historical development of biological knowledge in various parts of the biology curriculum provides students with a better understanding of the nature of science. By referring to the stories of some famous biologists, students can relive their lives: the ways they thought, the work they did, and the joy and frustrations they experienced. It is important that the focus of these studies should be on analyses and deductions using evidences derived from experimental work. Students should not be expected to study all these examples, or to link the names with

particular pieces of work or to be familiar with details of techniques. Teachers can use historical stories to bring out the nature of science and to elaborate various aspects of scientific inquiry, and biology in different historical and cultural perspectives. This may foster a positive attitude towards the learning of biology. In addition, students should be aware of the contributions of other science disciplines, e.g. physics and chemistry, to the development of biological knowledge.

Example:

In Section 3 Genetics and Evolution, students are suggested to read some stories of the following biologists:

- Mendel's work on garden peas.
- Griffith's work on *Pneumococcus*
- Hershey and Chase's work on T_2 phage: DNA, not protein, is the hereditary substance.
- Watson and Crick's work on the double helix model of DNA.
- Stahl and Meselson's work on semiconservative nature of DNA replication.
- Chargaff's work on the base composition of DNA.
- Morgan as the co-founder of modern genetics, concluded that genes are located on chromosomes, and invented techniques of genetic mapping.

Practical work and scientific investigations

Biology is a science subject and thus practical work is essential for students to gain personal experiences of science through hands-on activities, and to develop the skills and thinking processes associated with the practice of science. Participation in these activities encourages students to bring scientific thinking to the processes of problem solving, decision-making and evaluation of evidence. Practical activities should be integrated with the learning of scientific principles as far as possible, so that students can associate their experimental findings with what they have learned. Teachers are encouraged to provide a wide range of practical activities, from practical work such as dissection and observation of plant and animal cells to open-ended investigations. These would foster the development of students' practical skills as well as scientific process skills.

Scientific investigations involve defining problems, formulating hypotheses, designing and conducting investigations, and interpreting results. Instead of solely verification, these kind of activities allow students to understand how science is done, how to clarify questions, how

to design an experiment, how to record and interpret data, how to communicate the knowledge generated, and how to evaluate the experimental design and results. It should be noted that the processes of inquiry, experimental design, investigation, and analysis are as important as finding correct answers. Students will master much more than facts and manipulative skills, and they will learn to be critical thinkers.

A balanced biology teaching plan should be organised to have a significant amount of practical and investigative works so that students are provided with opportunities to develop their higher order thinking skills as well as practical skills. Teachers may design or adopt practical work and investigation to bring out the elements of learning in an effective manner. In particular, practical work and investigation closely related to relevant contexts will certainly enhance learning effectiveness.

Practical work and investigations should be performed by students under proper teacher supervision to ensure that safety measures are observed. Teachers are advised to try out new or unfamiliar practical work beforehand so that any potential risks can be revealed and avoided.

Group discussion/Role-play/Debate

Group discussion, role-play and debate, which allow students to be actively engaged in their learning process, are effective ways to motivate learning and to develop generic skills such as collaboration, communication, critical thinking, and problem-solving. Students are involved in the processes of researching and analysing information, organising and presenting ideas in a clear and logical manner, and making judgments from arguments. It is particularly suitable for dealing with controversial issues such as "the validity of evolution theories" and "the dilemma between urbanisation, industrialisation and conservation". In such activities, students may first be given some background information of a specific case and time to think individually. They are then divided into groups to express their opinions and exchange views. Students should be encouraged to interact with each other and the teacher plays the role of a facilitator who guides students to work along the right direction, and provides feedback on their performance. These activities provide meaningful opportunity for students to explore the viewpoints of different roles. By role-playing different characters in some given situations involving biological, environmental or ethical issues, students can explore the experiences and viewpoints of these characters and, by trying to justify their behaviours, widen the perspective of the matter being considered.

Project learning

Project work provides inviting and productive learning experiences, and bridge the gap between learning in school and learning in the real world. It enables students to connect knowledge, skills, values and attitudes, and to construct knowledge through a variety of learning experiences. Project work usually is completed within a reasonable time frame, ranging from a week to a term, depending on its nature. It usually consists of several stages, including planning (goal setting, identifying foci of projects), gathering (researching, finding resources, collecting data), processing (analysing, sorting and synthesising information), and applying (prioritising tasks, reviewing, revising, evaluating), and the final stage of presentation may be done in the form of a book report, multimedia presentation, poster design or model construction. Group projects can be arranged to develop students' collaboration and study skills. Suggested project work ideas are listed in the possible learning and teaching activities column of each section. Teachers or students should make use of some of these ideas to enhance biology learning in suitable contexts. Students could learn better by conducting individual or group project work on particular biology and cross-curricular topics or issues.

Example:
In Section 6 Health and Diseases, it is suggested that students should conduct a project using "Non-infectious diseases" as a main theme. Through brainstorming and mind-mapping on the ideas emerging from this theme, students could develop their own areas of study or project proposals. Teachers should provide sufficient guidance and time for students to work on the set project, and monitor their progresses with suitable instruments, e.g. log book.

Problem-based learning

Problem-based learning is an instructional method that challenges students to "learn to learn", and to work cooperatively in groups to seek solutions to real world problems. It allows students to think critically and analytically, and to find and use appropriate learning resources. Problems are used to engage students' curiosity and initiate learning of the subject matter. During the process of solving problems, students learn new knowledge, problem-solving skills and associated skills of teamwork, leadership, and communication. It may start with a poorly defined or open-ended problem, or a real-life scenario. Students work collaboratively to define the problem, generate questions, hypothesise, anticipate needed information,

generate alternatives, and develop solutions to the problem. Teachers become facilitators of learning and observers of students' contributions and participation. Students are motivated by actively engaging in the learning process and taking responsibility for their own learning.

Example:
In Section 12 Continuity of life, growth and development, a problem such as "a 48-year old woman is worried about having a baby at an old age" can be used to help students to:

- apply understanding of biological principles to real life situations,
- understand some reproductive technologies,
- recognise the relationship between the maternal age and the occurrence of some genetic diseases in babies,
- be aware of the ethical and social issues associated with the uses of some reproductive technologies.

The following questions can be raised for discussion:

- What is menopause?
- Are women more susceptible to have babies with genetic disorders as they get older? Any statistics to support or any scientific explanation?
- Should the pregnancy be terminated if the foetus is found to have genetic disorders?
- At what maternal age is it NOT suitable to give birth to a baby?
- Should doctors deny certain people the right to use reproductive technology? Explain your answer.
- What is super-ovulation? Would there be any side effects?
- How is *in vitro* fertilisation carried out?
- What will be the ethical and legal implications if the egg comes from a donor instead of from the mother?
- Are there such services available in Hong Kong?

Issue-based learning

Issues result from differences in opinion about what is true or what should be done. Issue-based learning allows students to learn in a meaningful context. Topics such as applications of genetics and environmental conservation generates lots of issues which could help students to bring together the scientific knowledge or concepts they have acquired and the societal implications of using technology. These issues contain moral and value components that provide students with opportunities to consider the implications of various

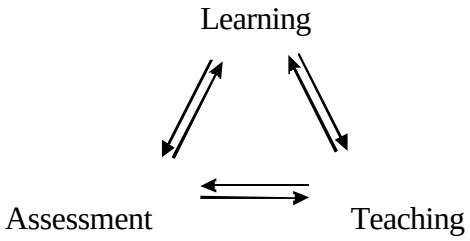
points of view in the light of fundamental societal values such as respect for life, respect for others, respect for the environment, freedom, justice, etc. Some issues may be rather sensitive, e.g. the theories of evolution, which involve religious perspectives, and deeply held viewpoints and beliefs. Teachers should note that these issues are treated sensitively and rationally, and provide ample opportunities for students to share their personal opinions and beliefs, rather than imposing their own values on their students who should be exposed to all other perspectives and viewpoints.

Example:

In Section 12 Continuity of life, growth and development, the issue "Should we clone mammals for human uses?" could be raised for discussion. This issue links the concept of cell divisions, cloning, biotechnology, and societal implications such as the future benefits and potential hazards to the environment, and explore into the religious and ethical points of view.

IV. ASSESSMENT

Assessment, the practice of collecting evidence of students' progress in learning, aims for the improvement of learning and teaching. As an integral part of the learning and teaching cycle, it should not be treated as a separate stage at the end of teaching, nor should it be taken as a synonym to "marking".



Assessment provides:

- information for teachers to help them identify students' needs and to assess the progress of students' development of skills, understanding, attitudes, and interest;
- information for students about their mastery of knowledge, skills and attitudes, and growth, and their strengths and weaknesses;
- a basis for grading students, reporting their progress, and helping them set realistic goals for future undertakings; and
- information that can be used to help revise teaching strategies and the curriculum.

A. Formative assessment and summative assessment

There are various categorisations of types of assessment; formative assessment and summative assessment are two common types of categorisation. Formative assessment and summative assessment serve different and distinct purposes, and each has its own place. They complement each other and both should be used to form a comprehensive profile of a student's achievements.

Formative assessment is assessment for learning, and is a day-to-day ongoing process happening all the time. Formative assessment should be based on learning intentions developed by the collaborative efforts of both students and teachers. The learning intentions should be geared to the aims and objectives of the curriculum. Specific comments and feedback should be made to students reflecting how well they have accomplished the learning intentions. Based on these comments and feedback, students would be able to develop plans

for improvement. Teachers would be able to adjust their teaching plans/strategies to enhance students' learning. Oral questioning, observation of students, project work, practical work and assignment are common modes of formative assessment. Written tests can also be a form of formative assessment, provided that specific comments and feedbacks are given to the students.

Summative assessment is assessment of learning. It is usually applied at the end of a term or a unit. It provides information about what students have learned. Tests and examinations in schools as well as public examinations, which are common examples of summative assessment, measure students' standards or attainments, and report them in term of marks or grades. However, since summative assessment could not provide immediate feedback for setting improvement in learning and teaching, it should not be treated as the only means of assessment. When setting summative assessments for this curriculum, the overview, the learning objectives and the expected learning outcomes listed in each section should be referred to.

B. School-based assessment and public examinations

School-based assessment refers to all sorts of assessment that are administered in schools. It has advantages of flexibility and intimacy with the learning and teaching processes. It could be more informative to students and teachers involved in the teaching and learning cycle than public examinations as assessment task can be designed to match students' learning experiences.

Public examinations provide information about the standards and achievements of students based on the aims and objectives of the curriculum guides. They are intended to provide fair testing of all students for the purposes of certification and selection. Apart from these functions, public examinations can also have a positive backwash on learning and teaching by setting questions on authentic contexts and assessing higher order cognitive abilities, thus contributing to the reinforcement of the aims of the curriculum, enhancing learning and teaching. Feedback provided in the annual subject reports provides valuable information for teachers to adjust teaching with a view to improving student learning.

	Formative Assessment	Summative Assessment
School-based Assessment	Oral questioning, observation, project work, assignment, quiz and test	Test and examination
	Teacher Assessment Scheme*	
Public Examination		Written examination and practical examination**

* *Teacher assessment scheme is compulsory for all school candidates.*
** *Practical examination is for private candidates only.*

C. Guiding principles for assessment

1. Assessment should aim at enhancing the self-esteem and motivation of an individual student.
2. Teachers should develop a learning culture that values the attitudes to learning with trusting relationships.
3. Teachers should take into consideration the prior knowledge and previous learning experiences of students when setting assessment tasks.
4. Assessment tasks should take into account the aims and objectives outlined in this Biology curriculum and assessment guide. In particular, the three domains of objectives: knowledge and understanding, scientific process skills, and values and attitudes, should be addressed.
5. A variety of assessment modes should be adopted to cater for the diverse needs, abilities, strengths and weaknesses of students, e.g. projects, observation, tests, examinations, practical work, and portfolios.
6. Self-assessment and peer assessment should be encouraged, with a view to empowering students to assess their own achievement and those of their peers against learning intentions. Self-assessment provides an insight into how students perceive their own progress, thus promoting reflective thinking and self-improvement, which are desirable qualities of independent learning. Peer assessment allows students to reflect from other perspectives how well one has performed, and how to perform even better through learning from each other.
7. Unexpected outcomes should be anticipated from students who sometimes do not follow the prescribed path of learning. Assessment might lead to a disclosure of such unexpected learning outcomes.

D. Assessment in schools

A number of assessment modes can be used in the learning and teaching of A-Level Biology. Teachers should have well-thought-out plans on how to assess students' achievements and make full use of various learning and teaching activities to carry out assessment. Teachers should let students know how they will be assessed.

1. Paper-and-pencil tests

Paper-and-pencil tests have been widely employed as the major methods of assessment within schools. However, the prolonged reliance on this type of assessment would have a narrowing effect on learning. Teachers should avoid testing only basic information recall and should try to construct test items that assess the understanding of concepts, problem-solving abilities and higher order thinking skills. Incorporation of open-ended questions in tests and examinations could help evaluating students' creative and critical thinking skills.

Example:

In Section 3 Genetics and Evolution, the following question can be set:

"Discuss the impacts brought by the Human Genome Project."

When answering the question, students might:

- consider the scientific facts and concepts of the Human Genome Project;
- evaluate the potential benefits and hazards;
- evaluate the associated ethical and social issues; and
- make personal judgement.

Their critical thinking skills could thus be developed and assessed.

Teachers should analyse students' performance in tests and examinations, and use the information for future planning as well as helping students to identify what or where their strengths and weaknesses are.

2. Oral questioning

Oral questioning can provide teachers with specific information on how the students think in certain situations. Students' responses often provide clues to their strengths, weaknesses, misunderstanding, level of understanding, interests, attitudes and abilities. Teachers are encouraged to use a wide range of questions, from fact finding, problem posing, reason seeking, to those that promote higher levels of thinking, and allow for a variety of acceptable responses. Teachers should allow time for students to respond and listen carefully to their responses. Questions or problems, based on information which is unfamiliar to students, could be set. Such questions can assess students' abilities to apply principles and concepts they learned to a novel situation in a logical and deductive manner.

Example:

In Section 5 Human Activities and the Environment, teacher could ask students,

- "Based on what you know about the renewable and non-renewable resources, what resources do you think are becoming limiting?"
- "What would happen in ten years' time if we do not take any measure to control the human population now?"

3. Observation

While students are working in groups or individually, teachers could take the opportunity to observe and note various aspects of students' learning. Teachers should keep brief anecdotal records and use such information for making further judgements about students' learning.

Some suggested aspects that teachers could focus on during observation include:

In practical sessions

- how students organise their practical work
- the use of equipment and apparatus
- the safety measures and precautions taken
- the activities preferred
- how students collect, record and interpret data
- the interaction among students

In other situations such as group discussions or presentations

- the strategies students take to solve problems
- how students listen to, negotiate and compromise with others
- their attitudes to work, e.g. perseverance, organisation, independence, willingness to address difficulties

4. Project work

Project work, a powerful learning and teaching strategy as well as assessment strategy, promotes self-directed, self-regulated and self-reflecting learning. It provides ample opportunities for students to apply what they have learned, and employ various skills and thinking processes such as identifying problems, formulating hypotheses, designing and implementing strategies and evaluation. It also provides a real context to authentically assess students' achievement in a variety of generic skills, e.g. student's creativity, communication skills, collaboration skills, willingness to share, to listen, and problem-solving abilities. Teachers can make use of the suggested project work listed in the *Possible learning and teaching activities* column of each section, and develop appropriate criteria to assess the ideas being formed, skills being developed, and values and attitudes being demonstrated by students during the process of doing project work.

5. Assignment

The assignment, widely used in the learning and teaching processes, is a good tool of formative assessment as it continuously reflects students' efforts, achievements, strengths and weaknesses. A variety of assignment tasks should be designed to allow students to express their thoughts, ideas, creativity and originality upon their understanding of concepts. These include exercises, essays, laboratory reports, poster or leaflet design, and model construction. The assignment tasks should be aligned with the learning objectives, instructional strategies and learning activities. Specific comments, feedback and suggestions for improvement should be given to inform students of their progress.

Teachers can ask students to select a topic of interest for searching information. Students are required to summarise their findings and devise their own ways to present their work, e.g. role play, essay, poster design. Teachers should take note of how students organise the materials, the language used, the breadth and depth of the treatment, and the clarity of concepts. As a means of evaluation, assignment can also reflect the effectiveness of teaching, and provide

feedback upon which teachers can set further targets for students, and make appropriate adjustments in their teaching.

6. Practical work and scientific investigation

Practical work, an essential element in the study of biology, provides a meaningful context for students to apply their knowledge and skills. It offers students hands-on experiences to explore or investigate, and opportunities to show their resourcefulness, interest, ingenuity, originality, creativity, appreciation and perseverance. Teachers can use appropriate criteria and standards to assess students' scientific knowledge, as well as application of the scientific method, ability to handle data, awareness of safety, interest and enthusiasm in the work being done. Students' written laboratory or investigation reports can serve as an effective means of assessing students' performance in scientific activities and provide a more complete picture about student learning.

The Teacher Assessment Scheme of practical work, compulsory for all school candidates, is an ongoing assessment process for the development of students' practical skills. It also provides valuable information and feedback to the learning and teaching cycle. It should not be treated solely as an examination instrument for generating marks and grades. Teachers should refer to the regulations, guidelines, methods and criteria of assessment, given in the Handbook for A-Level Biology Teacher Assessment Scheme issued by the Hong Kong Examinations Authority.

7. Concept mapping

Concept mapping is an effective way of allowing students to think aloud and actively make sense of what they have learned, linking up related concepts. Concept maps are useful in providing teachers and students with an understanding of prior knowledge, and the conceptual gains that are made during a unit of study.

Example:

In 4.3.2 Energy flow and nutrient cycling, teachers could ask students to

- brainstorm ideas in the mind,
- write down what they know about sources of nutrients, types of nutrients, processes of change of nutrients and forms of nutrients in organisms,
- use a concept map to relate these ideas.

Teachers can then use the concept maps constructed as a starting point for discussion and teaching. The maps are then revised and refined throughout the learning process and used as a tool to clarify and organise the concepts formed.

8. Portfolio

Portfolio assessment is a way of documenting students' learning and keeping records of students' work as they progress throughout the year. It aims to show the continuous effort of the students. Samples of student work should be collected at regular intervals and dated, forming a cumulative file. A student's work folder provides evidence of student achievement of specified competencies, and information on the level of understanding, the logical thinking processes, and the need for remediation, consolidation or extension work. It also allows students to discuss their achievements and difficulties with their teachers, parents and fellow students. Laboratory reports, biological drawings, newspaper cuttings, concept maps, projects, exercises and written assignments could all be included in the portfolio to document changes in breadth and depth of students' understanding.

9. Computer-based assessment

Computer-based assessment is a tool that promotes self-directed and self-reflecting learning. The use of computer programmes enables students to choose among a question bank, and assess what they have learned throughout the learning and teaching processes. The computer-marked assessment on screen allows students to make decisions at their own pace and in the comfort of privacy. Students can gain an instant feedback on whether the choices were the best ones, and why other choices were not so good or entirely wrong, and learn from their mistakes.

The modes of assessment suggested above are by no means exhaustive. All assessment data collected should be treated as valuable information and contribute to the improvement of learning and teaching. Adopting a combination of assessment modes enables teachers to build up a comprehensive picture of students' achievements. Teachers should explore other assessment opportunities to best suit the needs of their schools and students.

E. Public examination

For A-Level Biology, the public examination consists of written papers and a Teacher Assessment Scheme (TAS). The following assessment objectives of the examination reinforce the aims and objectives of this curriculum:

1. to recall and show understanding of biological facts, concepts, principles and the relationships between different topic areas of the curriculum framework;
2. to apply biological knowledge, concepts and principles to explain phenomena, observations and to solve problems;
3. to formulate working hypotheses, to plan and to perform tests for them;
4. to show practical skills related to the study of Biology,
5. to present data in various forms (tables, graphs, charts, drawings, diagrams etc.) and transpose them from one form into another;
6. to analyse and interpret data (including numerical and non-numerical data such as in the form of continuous prose, diagrams, photographs, charts and graphs etc.); to make logical deductions, inferences and draw conclusions from them;
7. to evaluate evidence and detect errors;
8. to select, synthesise, and communicate ideas and information clearly, precisely and logically;
9. to show understanding of the applications of biology to everyday life and the contributions of biology to the modern world;
10. to show awareness of the ethical, moral, social, economic and technological implications of biology; and
11. to make suggestions, choices and judgements based on biological knowledge and principles.

Details of paper structures can be found in the Hong Kong Advanced Level Examination Regulations and Syllabuses Handbook.

The Teacher Assessment Scheme brings together school-based assessment and public examination. The students' Biology teachers are the assessors in schools (thus a kind of school-based assessment), and the assessment marks awarded by the teachers will contribute to the overall achievements of the students in the public examination in addition to the achievements shown by the students in the written papers. The TAS essentially measures skills on experimental design and the performance of experiments by students, report writing skills on biology investigations, and a range of practical skills some of which are unique to

Biology (e.g. microscopy skill, dissection skill, ecological field study skill and drawing skill). The A-Level Biology TAS also measures the affective qualities of the students such as:

- an appreciation of the wonders of the living world,
- a respect for all living things,
- a demonstration of interest, eagerness, curiosity and self-initiative in the study of Biology,
- self-reliance, resourcefulness and the ability to work with little supervision,
- willingness to tackle problems and persistence in approach, and
- cooperation in team work.

The detailed assessment criteria, rules and regulations as well as assessment modes of the TAS can be found in the A-Level Biology TAS Handbook published by the Hong Kong Examinations Authority. In the TAS, teachers are required to carry out continuous assessment over the entire A-Level course, thus accumulating a number of assessments on various tasks, in this way the TAS is summative in function. The fact that a better mark will be taken to calculate the final TAS mark serves to encourage improvement in learning which indicates the formative nature of the Biology TAS. In the TAS, teachers are encouraged to provide feedback for improvement through comments made on the students' work. Thus its role in formative assessment is also significant.

Appendix: Reference Books

Title	Author	Publisher	Year of Publication
An Introduction to Genetic Engineering (Studies in Biology)	Nicholl, D.S.	Cambridge University Press	1994
Anatomy and Physiology in Health and Illness (8th Edition)	Wilson, K.J.W. & Waugh, A.	Churchill Livingstone	1996
Animal Biology	Jurd, R.D.	BIOS Scientific Publishers	1997
Applied Ecology	Allen, D., Jones, M. & Williams, G.	Cambridge University Press	2001
Assessing Student Learning: from Grading to Understanding	Allen, D. (Ed.)	Teachers College Press	1998
Biodiversity	Wilson, E.O.	National Academic Press	1989
Biological Science 1 & 2 (3rd Edition)	Green, N.P.O., Stout, G.W., Taylor, D.J. & Soper, R.	Cambridge University Press	1998
Biology	Mawby, P.J. & Roberts, M.B.V.	Longman	1991
Biology (4th Edition)	Solomon, E.P., Berg, L.R., Martin, D.W. & Villee, C.	Saunders College	1998
Biology 1 & 2	Jones, M. & Gregor, J.	Cambridge University Press	2001
Biology AS	Baile, M. & Hirst, K.	Collins	2001
Biology Now!	Riley, P.D.	John Murray	1998
Biology: A Functional Approach (4th Edition)	Roberts, M.B.V.	Thomas Nelson	1991
Biology: Principles and Processes	Roberts, M., Reiss, M. & Monger, G.	Thomas Nelson	1993
Biology: The Network of Life	Mix, M.C., Farber, P. & King, K.I.	Harper Collins	1992
Biotechnology: Selected Topics	Teasdale, J.	Cheltenham Thornes	1987

Title	Author	Publisher	Year of Publication
Chemistry for Biologists	Fisher, J. & Arnold, J.R.P.	BIOS Scientific Publishers	1999
Complete Biology	W.R. Pickering	Oxford University Press	2000
Current Trends in Biology	Riggs, A., Farmer, B. & Olejnik, I. M.	Stanley Thornes	1993
DNA Fingerprinting (2nd Edition)	Krawczak, M. & Schmidtke, J.	BIOS Scientific Publishers	1998
DNA Sequencing: From Experimental methods to Bioinformatics	Alphey, L.	BIOS Scientific Publishers	1997
Ecology	Mackenzie, A., Ball, A.S. & Virdee, S.R.	BIOS Scientific Publishers	1998
Evolution	Gamlin, L.	Dorling Kindersley	1993
Five Kingdoms: An Illustrated guide to the Phyla of Life on Earth (3rd Edition)	Margulis, L. & Schwartz, K.V.	Freeman	1998
GCSE Science Double Award Biology	Gater, S. & Wood-Robinson, V.	John Murray	1996
Genetics	Winter, P.C., Hickey, G.I. & Fletcher, H.L.	BIOS Scientific Publishers	1998
Good Practice in Science Teaching: What research has to say	Monk, M. & Osborne, J. (Ed.)	Open University Press	2000
Growth, Development and Reproduction	Taylor, D.	Cambridge University Press	2001
How Nature Works	Burnie, D.	Dorling Kindersley	1999
Human Anatomy & Physiology (2nd Edition)	Carola, R., Harley, J.P. & Noback, C.R.	McGraw-Hill	1992
Immunology	Lydyard, P.M., Whelan, A. & Fanger, M.W.	BIOS Scientific Publishers	2000
Investigating formative assessment	Torrance, H. & Pryor, J.	Open University Press	1998

Title	Author	Publisher	Year of Publication
Investigations	Kanuffman, S.A.	Oxford University Press	2000
Issues in Science Education	Rhoton, J. & Bowers, P. (Ed.)	The National Science Teachers Association	1996
Laboratory Manual for Human Anatomy & Physiology	Bruce, A.S., Cocanour, B., Namm, T. & Farina, J.P.	McGraw-Hill	1992
Life	Burnie, D.	Dorling Kindersley	1994
Life Story	Sullivan, F.M.	Oliver & Boyd	1992
Life: An Introduction to Biology (3rd Edition)	Beck, W.S., Liem, K.F. & Simpson, G.G.	HarperCollins	1991
Microbes and Diseases	Hudson, T. & Mannion, K.	Cambridge University Press	2001
Microbiology	Nicklin, J., Paget, T., Graeme-Cook, K. & Killington, R.	BIOS Scientific Publishers	1999
Microbiology and Biotechnology	Lowrie, P. & Wells, S.	Cambridge University Press	2000
Molecular Biology (2nd Edition)	Turner, P.C., McLennan, A.G., Bates, A.D. & White, M.R.H.	BIOS Scientific Publishers	2000
Physiological Processes: An Introduction to Mammalian Physiology	Stanier, M. & Forsling, M.	McGraw-Hill	1990
Physiology (4th Edition)	Berne, R.M. & Levy, M.N.	C.V. Mosby	1998
Physiology of the Human Body (6th Edition)	Guyton, A.C.	Saunders College	1989
Plant Physiology	Salisbury, F.B.	Wadsworth	1991
Practical Skills in Biology (2nd Edition)	Jones, A., Reed, R. & Weyers, J.	Longman	1998
Practical Skills in Biomolecular Sciences	Reed, R., Holmes, D., Weyers, J. & Jones, A.	Prentice Hall	1999
Projects in Biology	Knowles, M.	Basil Blackwell	1988

Title	Author	Publisher	Year of Publication
Random House Webster's Dictionary of Scientists		Random House	1997
Revised Nuffield Advanced Biology: Practical Guides Books 1-7	Monger, G. (Ed.)	Longman	1985
Revised Nuffield Advanced Biology: Study Guides I & II	Monger, G. (Ed.)	Longman	1985
Revised Nuffield Advanced Biology: Teachers' Guide I & II	Monger, G. (Ed.)	Longman	1985
Science & Technology in Society (SATIS)	The Association for Science Education	The Association for Science Education	1986
Science & Technology in Society (SATIS) 16-19	The Association for Science Education	The Association for Science Education	1990
Science for All Americans	Rutherfod, F.J.	Oxford University Press	1990
Tackling Biology Projects	Wedgwood, M.	Macmillan	1987
Teaching Secondary Biology	Reiss, M. (Ed.)	John Murray	1999
Understanding Biology for Advanced Level (4th Edition)	Toole, G. & Toole, S.	Stanley Thornes	2000
Understanding Gene Therapy	Lemoine, N.R.	BIOS Scientific Publishers	1999
What Research says to the Science Teacher (Volume Seven): The Science, Technology, Society Movement	Yager, R.E. (Ed.)	National Science Teachers Association	1993
不可思議的生物科技	**江晃榮**	**世茂出版社**	2001
分子生物學基礎	**史濟平 編**	**高等教育出版社、施普林格出版社**	2000
分子生物學實驗技術	**郝福英、朱玉賢、朱聖庾、李雲蘭、周先碗、李茹**	**北京大學出版社**	1999
世界著名科學家傳記生物學家 2		**臺灣書店**	1999
生物工程與生命	**羅琛 編**	**高等教育出版社、施普林格出版社**	2000

Title	Author	Publisher	Year of Publication
生物化學	古練權	高等教育出版社	2000
生物多樣性		遠哲科學教育基金會	2000
生物技術製藥	熊宗貴	高等教育出版社、施普林格出版社	1999
奇妙的科學實驗室生物篇	普拉特．范克莉芙、珍妮絲	浙江科學技術出版社	1999
拯救生物多樣性	楊悅、徐家秀	海洋出版社	2000
科學圖書大庫生態學概論	郝道猛	徐氏基金會出版	1997
偉大的生物學家		錦繡文化	1996
動物生物學	許崇任、程紅	高等教育出版社、施普林格出版社	2000
問個明白 1 – 發明家和科學家的故事	葉永烈	突破出版社	1999
問個明白 2 – 中西科學奇才	葉永烈	突破出版社	1999
基因組譜系解密	凱文、戴維斯	時報文化出版社	2001
基礎生物	于名振	徐氏基金會出版社	1992
現代生物技術導論	陳章良、瞿禮嘉、胡萍	高等教育出版社、施普林格出版社	1998
細胞生物學	翟中和、丁明孝、王喜忠	高等教育出版社、施普林格出版社	2000
植物分子生物學實驗指南	克萊森、格瑞森姆、瓦爾納、卡什莫爾、馬利加	科學出版社	2001
進化新解說	方舟子	萬里出版社	1999
微生物學	沈萍	高等教育出版社	2000
達爾文與進化論	麗貝卡．斯泰福	百花文藝出版社	2001
複製動物之謎	吳志堅、朱婉兒	壹出版	1999
諾貝爾（科學巨人叢書）	羅范懿	三聯書店	1999
遺傳學	馬丁．布魯克斯	三聯書店	2001