Appendix I

Updated Biology (Secondary 4-6) Curriculum and Assessment Framework

(Consultation Draft)

Curriculum Development Council
June 2026

Preamble

The Updated **Biology *(Secondary 4-6) Curriculum and Assessment Framework* (*Consultation Draft)*** sets out the proposed update of the Biology Curriculum for Senior Secondary Level. This curriculum document presents the proposed curriculum rationale, curriculum framework and assessment framework of Biology (Secondary 4 – 6), including the learning targets, curriculum emphases, curriculum contents and public assessment. It also includes two Annexes, namely "The Use of Digital Educational Tools and Artificial Intelligence for Learning, Teaching and Assessment of Biology" and "Connections across Learning of Senior Secondary Science Subjects", which provide further guidance on promoting effective pedagogical use of digital and AI tools, as well as strengthening curriculum connection among the science subjects. The views collected from this consultation will be taken into consideration in the development of *Science Education Key Learning Area Biology Curriculum and Assessment Guide (Secondary 4-6)*.

Views and suggestions on this document may be sent to:

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Chapter 1 Introduction

This chapter provides the background, rationale and aims of Biology as an elective subject in the three-year senior secondary curriculum, and highlights how it articulates with the junior secondary curriculum, post-secondary education, and future career pathways.

1.1 Background

Science is the study of phenomena and events around us through systematic observation and experimentation. Science education cultivates students' curiosity about the world and enhances scientific thinking. Through the study of science, students will develop scientific knowledge and skills to help them evaluate the impact of scientific and technological developments, which will prepare them to become lifelong learners in science and technology and responsible citizens, and to contribute to our scientific and technological world.

Building on the firm foundation of science developed at the primary level and junior secondary level, a diversified senior secondary Science Education curriculum has been developed with different elective subjects for students to choose from, and to cater for their different interests and aptitudes. Biology is one of the three elective subjects developed under the Science Education Key Learning Area in the senior secondary curriculum.

The Biology Curriculum and Assessment Guide (Secondary 4 – 6) was first published in 2007. With the implementation of the New Academic Structure in senior secondary in 2009 and the inaugural of Hong Kong Diploma of Secondary Education Examination in 2012, the Short-term Review and the Medium-term Review were conducted in 2012 and 2014 respectively to fine-tune the senior secondary Biology curriculum and assessment. Following the recommendation set out in the two reviews, the Biology Curriculum and Assessment Guide (Secondary 4 – 6) (2007) was updated in January 2014 and November 2015.

In 2017, the Task Force on Review of School Curriculum (Task Force) was set up to holistically review the primary and secondary curricula. Upon completion of the review, the Task Force submitted the final report entitled "Optimise the curriculum for the future, Foster whole-person development and diverse talents" (review report) in September 2020. In tandem with one of the recommendations set out in the review report, the four senior secondary (SS) core subjects were optimised according to the proposals put forward by the Curriculum Development Council (CDC) and the Hong Kong

Examinations and Assessment Authority (HKEAA) Public Examinations Board with the aim of creating space for students and catering for learner diversity in 2021. Based on the experience of optimising the four SS core subjects, the EDB extend its review of the SS elective subjects, with the aim of further catering for learner diversity and fostering students' whole-person development.

Furthermore, with the rapid advancement of the science and technology and the changes brought about by the application of science, innovation and technology (I&T) to our society and our lives, together with the promotion of STEAM education in Hong Kong since 2015, Working Group on the Review of the Biology Curriculum (Working Group) was established under the CDC-HKEAA Committee on Biology in August 2020 to review and updates the biology curriculum. On top of creating space and catering for learner diversity, this review also aims to strengthen the articulation with the updated Science (Secondary 1-3) curriculum for further developing students' scientific literacy, enabling them to understand the impact and application of science for life and society, and fostering their science foundations for innovation and future pathways. The review also considered the directions set out in the report by the Task Force entitled "Optimise the curriculum for the future, foster whole-person development and diverse talents", and the related guidelines of the Curriculum Development Council's Secondary Education Curriculum Guide (CDC, 2017), the Science Education Key Learning Area Curriculum Guide (Primary 1 – Secondary 6) (CDC, 2017), and the Supplement to the Science Education Key Learning Area Curriculum Guide – Science (Secondary 1 to 3) Curriculum Framework (CDC, 2025).

1.2 Curriculum Rationale

This Biology Curriculum serves as a continuation of the Science (S1–3) Curriculum and builds on the strength of the current Biology curriculum. It will provide a range of balanced learning experiences so that students develop the necessary scientific knowledge and understanding, skills and processes, and positive values and attitudes embedded in the "Life and Living" strand and other strands of science education.

The emergence of a highly competitive and integrated economy, advanced scientific and technological innovations, and a growing knowledge base will continue to have a profound impact on our lives. Besides, there are regional, national and global issues related to biological sciences, like matters pertaining to the health and wellbeing of humans and other organisms as well as their populations in the ecosystem, the environment and sustainable development. In order to meet the challenges posed by these changes and issues, the Biology Curriculum, like other science electives, provides a platform

for developing students' scientific literacy and STEAM literacy, equipping them with essential scientific knowledge and skills and 21st century competencies for living in the society and life-long learning.

Through the learning of biology, students will acquire relevant procedural and conceptual knowledge to help them understand and address many contemporary and future biological issues in local, national and global contexts. They will become aware of the applications of science and technology to the society and the environment. In addition, students will develop a respect for the living world, an attitude of responsible citizenship and a commitment to promote ecological security, personal and community health, and national and global sustainable development.

These are necessary for personal development to enable students to contribute towards a scientific and technological world. The curriculum will prepare students for their tertiary studies, vocational training and careers in various fields of life science.

The rationales of the revised Biology (S4-6) curriculum are listed below.

1. **Conceptual understanding of life processes:**
   Assisting students in mastering the core concepts and fundamental principles of life processes, and understanding the complexity and interrelationships of living systems at different levels of organisation.
2. **Scientific thinking and scientific inquiry:**
   Developing students' scientific thinking skills, as well as their abilities to design and conduct experiments, collect and analyse data, and interpret results, and enhancing their problem-solving skills through scientific methods.
3. **Relevance to the real world:**
   Encouraging students to apply their biological knowledge to existing and emerging issues in the real world, such as human health, environmental protection, sustainable development, biotechnology and bioethics.
4. **Appreciation of life, biodiversity and value the ecosystem:**
   Cultivating students' appreciation of the diversity of life on Earth, and understanding the importance of environmental conservation, sustainable lifestyles and the responsible use of biological resources.
5. **Preparation for Higher Education and Careers:**
   Cultivating a solid knowledge foundation for students, and laying the groundwork for those interested in pursuing further studies in life sciences, healthcare, environmental science or related fields.

1.3 Curriculum Aims

The overarching aim of the Biology Curriculum is to provide biology-related learning experiences that enable students to develop scientific literacy, so that they can participate actively in our rapidly changing knowledge-based society, prepare for further studies or careers in the fields related to life science, and become lifelong learners in science and technology.

The broad aims of the Biology Curriculum are to enable students to:

- develop and maintain an interest in biology, a sense of wonder and curiosity about the living world, and a respect for all living things and the environment;
- understand and apply knowledge of biology, recognise the nature of science in biology-related contexts, and appreciate the relationships between biological science and other disciplines;
- develop the ability to make scientific inquiries; think scientifically, critically and creatively; and solve biology-related problems individually and collaboratively;
- understand the language of science and communicate ideas and views on biology-related issues;
- be aware of the social, ethical, economic, environmental and technological implications of biology, and be able to make informed decisions and judgments on biology-related issues;
- develop an attitude of responsible citizenship, and a commitment to promote personal and community health, and national and global sustainable development; and
- become lifelong learners of biology for personal development, and be prepared for further studies or future careers in fields related to biological sciences.

Chapter 2 Curriculum Structure and Organisation

The Biology Curriculum serves as a continuation of the Science (S1-3) Curriculum. With careful consideration of students' prior knowledge and everyday experiences, it is designed to cover the major aspects of biology at the senior secondary level.

At the heart of the curriculum are three key emphases: "Scientific Inquiry", "Science and Technology for Society and Environment" and "Nature of Science. These emphases, which stem from the curriculum rationale, guide the design and implementation of the curriculum, aiming to develop students' scientific literacy as well as their capacity and commitment to integrate and apply knowledge and skills across disciplines to address real-world challenges effectively and creatively.

The curriculum framework for Biology embodies the key knowledge, skills, values and attitudes that students are to develop at the senior secondary level. It forms the basis on which schools and teachers can plan their school-based curriculum, and design appropriate learning, teaching and assessment activities.

The curriculum framework has three interconnected components:
Learning Targets, Curriculum Emphases and Units for the Curriculum.

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2.1 Learning Targets

The learning targets of the curriculum are categorised into three domains: knowledge and understanding, skills and processes, and values and attitudes.

2.1.1 Knowledge and Understanding

Students are expected to:

- acquire knowledge and develop an understanding of biological principles, concepts, terms and facts;
- make connections between biological principles and concepts;
- learn the vocabulary, terminology and conventions used in biology;
- recognise the overarching concepts that can be used for understanding the connections and overarching coherence of the natural world;
- apply biological knowledge to familiar and unfamiliar situations;
- show an understanding of the applications and uses of biological knowledge in daily life; and
- be familiar with the current issues and developments in biology.

2.1.2 Skills and Processes

(1) Scientific thinking

Students are expected to:

- identify patterns and changes in the natural world, and predict trends from them;
- recognise the role of models in exploring phenomena and that models evolve as evidence changes; and
- integrate new concepts into existing knowledge framework and apply them to novel situations.

(2) Scientific method, investigations and problem solving

Students are expected to:

- make careful observations, ask relevant questions, identify problems and formulate hypotheses for investigations;
- identify assumptions, concepts and theories related to a problem posed;
- design, plan and conduct scientific investigations individually or collaboratively with appropriate instruments and methods, collect quantitative and qualitative information with accuracy, analyse and evaluate data, and draw conclusions from the evidence;

- predict results in scientific investigation, use scientific reasoning to draw conclusions, and to critically evaluate biology-related issues;
- use appropriate techniques to present scientific data and to convey concepts;
- assess the reliability and limitations of scientific measurements;
- propose further investigations or refinements if appropriate;
- develop the ability to think scientifically and creatively / innovatively for solving problems; and
- recognise the usefulness and limitations of scientific methods.

(3) Decision making

Students are expected to:

- make decisions based on evidence, arguments and scientific principles;
- recognise the importance of evidence in supporting, modifying or refuting proposed scientific theories;
- support judgements with reasoning, relevant biological knowledge and appropriate scientific principles; and
- identify the pros and cons of the applications of biological knowledge for informed decision-making.

(4) Practical work

Students are expected to:

- be aware of the potential risks associated with practical work / scientific investigations, and conduct the practical work / scientific investigations safely;
- evaluate experimental methods and suggest possible improvements; and
- use models to aid understanding of biological phenomena.

(5) Information handling

Students are expected to:

- search, retrieve, reorganise, analyse and interpret scientific information from a variety of sources;
- use information technology to process and present scientific information;
- evaluate the accuracy, credibility and relevance of information from secondary sources; and
- distinguish between fact, opinion and value judgement when processing scientific information.

(6) Communication

Students are expected to:

- use symbols, formulae, equations and conventions accurately;
- interpret scientific information in verbal, diagrammatic, numerical, tabular and graphical forms;
- organise and present ideas and arguments clearly and logically; and
- communicate ideas and views effectively with others, using the language of science including appropriate terminology and scientific conventions.

(7) Collaboration

Students are expected to:

- participate actively and contribute ideas in group discussions;
- negotiate, liaise and compromise to achieve group goals; and
- define roles and responsibilities and work effectively as part of a team.

(8) Learning and self-directed learning

Students are expected to:

- develop study and self-directed learning skills to enhance the effectiveness and efficiency of learning; and
- cultivate the habits, attitudes and competencies essential for lifelong learning.

(9) Use of digital tools and artificial intelligence (AI)

Students are expected to:

- use a range of digital tools, including AI, to search for, select and organise biological information for learning and scientific investigations;
- use appropriate digital tools (e.g. data-loggers and sensors, spreadsheets, graphing software, computer simulations and AI) to process, present and interpret experimental data and scientific information;
- evaluate the reliability, limitations and possible biases of information, explanations and visualisations produced by digital tools and AI, by comparing them with trusted scientific information sources; and
- demonstrate ethical and responsible use of digital tools and AI in science context, including protecting data privacy, acknowledging AI and digital assistance appropriately, and avoiding plagiarism.

2.1.3 Values and Attitudes

Students are expected to:

- appreciate the wonders and complexity of Nature, and show respect for all living things and the environment;
- develop their interests in the study of biology and/or further studies in biology-related fields;
- cultivate relevant scientific attitudes, like objectivity, integrity, enquiry, perseverance, prudency and inventiveness;
- recognise their responsibility for conserving, protecting and maintaining sustainable development of the environment;
- develop positive values and attitudes for responsible citizenship and a commitment towards adopting a healthy lifestyle, and promote community health;
- recognise the safety concerns in science investigations, practical work, and fieldwork, and committed to upholding safe practices throughout these activities;
- be aware of the dynamic nature of biological knowledge and appreciate the role of science and technology in understanding the living world;
- be aware of the application of biological knowledge in society and its social, ethical, economic and environmental implications;
- reflect on the ethical and society implications of digital technologies and AI in biology-related fields; and
- commit to lifelong learning, including the effective and responsible use of digital technologies and AI, to adapt to a rapidly changing knowledge-based society; and
- recognise the importance of maintaining food security, ecological security, resource security and biosecurity.

Figure 2.1 summarises some important learning targets of the curriculum.

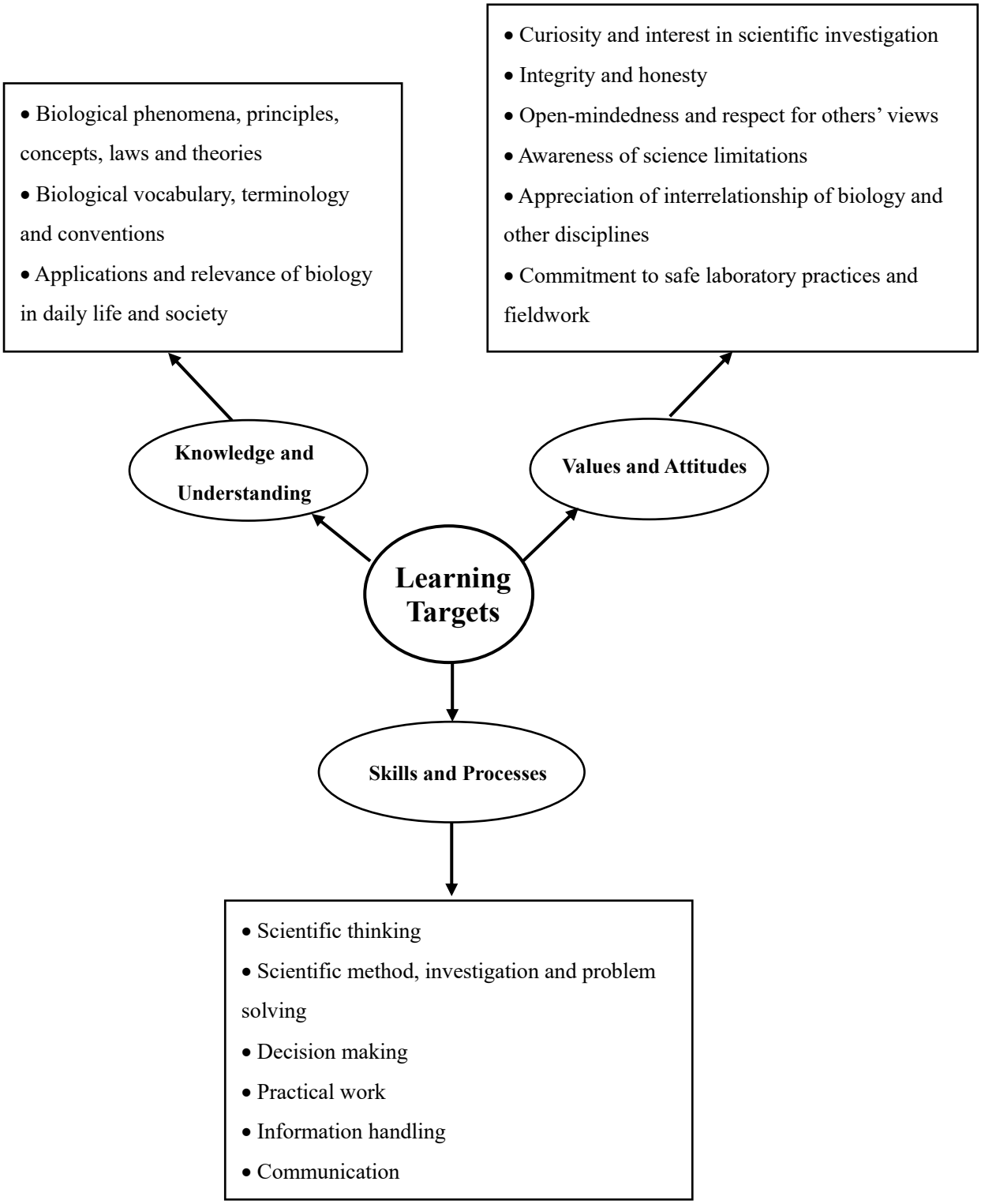

Figure 2.1 Learning Targets of the Biology Curriculum

2.2 Curriculum Emphases

Four Curriculum Emphases are included in the Biology Curriculum to help strengthen students' skills and processes for scientific inquiry and their understanding of the interconnections between science, technology, society and the environment, the nature of science, and the connections and overarching coherence between different biological concepts. The details of the four Curriculum Emphases are as following:

2.2.1 Scientific Inquiry

This should enable students to:

- make careful observations, ask relevant questions, identify problems, formulate hypotheses and make predictions for investigations;
- plan, conduct and write reports on scientific investigations;
- select and design appropriate methods of investigations for specific purposes;
- use appropriate instruments and apply proper techniques for carrying out practical work;
- identify and explain the importance of control variables in scientific investigations;
- recognise the importance of sample size, random sampling, replicates and repeat procedures in scientific investigations;
- pay attention to the precautions when conducting scientific investigations;
- classify, collate and display both first- and second-hand data;
- use diagrams, graphs, flow charts and physical models to represent the relationships arising from the data and biological phenomena;
- analyse and draw conclusions from data;
- understand that the process of scientific investigations includes analysing evidence and providing explanations based upon scientific theories and concepts; and
- formulate and revise scientific explanations and models using logic and evidence.

2.2.2 Science and Technology for Society and Environment

This should enable students to:

- develop sensitivity and responsibility in striking a balance between the needs of humans and sustainable development;
- appreciate the role of science and technology in understanding the living world;
- be aware of the application of biological knowledge in society and its social, ethical, economic and environmental implications;

- analyse ways in which scientific and technological advancement have influenced our lives, society, the environment and sustainable development;
- explore how biological knowledge is applied in technological applications and engineering;
- recognise that scientific knowledge can drive innovations and the development of new technologies, which in turn can fundamentally change the dynamics of the social, physical or natural systems;
- recognise that societal needs and changes in physical or natural systems can raise new questions for science and may even lead to new scientific discoveries; and
- recognise that knowledge and skills of biology / science are often integrated with other STEAM-related disciplines to address real-world problems/challenges;

2.2.3 Nature of Science

This should enable students to recognise that:

- Science attempts to explain natural phenomena based on the belief that there are consistent patterns in the universe.
- Scientific knowledge is durable and tentative.
- Scientific knowledge is supported by evidence and empirical standards.
- Scientific knowledge relies on creativity, innovation and scepticism.
- Scientists use different methods according to the nature of the phenomena studied and the history of the related disciplines.
- Scientific methods include the empirical testing of new ideas generated by deductive and /or inductive logic.
- Scientists are aware of possible bias in recording, reporting and interpreting data.
- Scientists form a community, in which they make open-minded discussions, critically assess and review new ideas, and share collective wisdom.
- Science has its limitations.

2.3 The Units for the Curriculum

There are thirteen Units in the Biology curriculum. In Unit I to Unit XII, topics are organised under a main theme for the development of understanding of various biological principles and concepts, and skills and processes in students. Unit XIII lists out the skills, process and practices for scientific investigation.

2.3.1 Core part and Extension part

The Curriculum Units, Unit I – XII, is further demarcated into Core and Extension parts to cater for students of different abilities and needs. The Core part covers a range of content that enables students to develop an understanding of fundamental biological principles and concepts, and the scientific inquiry skills. The Extension part covers a range of content that are built on or the applications of the knowledge and skills learned in the Core part.

2.3.2 Time Allocation

A total of 250 hours should be allocated to cover the Biology Curriculum. Within this, 20 hours are allocated for scientific investigations to further develop students' skills and attitudes in scientific inquiry. An estimate of the number of hours required for each Unit is shown below to provide some guidance on the weighting to be placed on individual Units:

Unit		***Suggested lesson time (Hours)***		
		Core	Extension	Total
1	Cells	12	-	12
2	Cellular energetics	15	-	15
3	Life processes in plants	18	-	18
4	Human physiology 1	31	5	36
5	Human physiology 2	-	15	15
6	Organisms and their environment	14	2	16
7	Continuity of life	24	-	24
8	Genetics	19	-	19
9	Evolution and biodiversity	9	4	13
10	Biotechnology	-	22	22
11	Health and diseases	8	12	20
12	Conservation and sustainable development	11	9	20
	Sub-total:	161	69	230
13	Scientific Investigations			20
	Total lesson time:			**250**

Remarks:
The lesson time for each elective subject is 250 hours (or 10% of the total allocation time) for planning purpose, and schools have the flexibility to allocate lesson time at their discretion in order to enhance learning and teaching effectiveness and cater for students' needs.

2.3.3 Organisation of Unit I to XII

Each of these Units is organised in the following way:

(1) Overview

This part introduces the main theme and focuses of the content for each Unit. It suggests the overarching expected learning outcomes of the Unit.

(2) Topics

This column of the table lists the intentions of learning (students should learn) in the content domain of the curriculum. It outlines the major content areas of each Unit that students should learn. **Topics in the Extension Part (extension topics) are underlined**.

(3) Learning outcomes

This column of the table lists the learning outcomes (students should be able to) to be achieved by students, in terms of knowledge and understanding (denoted by **K**) and skills and processes/practices (denoted by **S**) of the curriculum. These learning outcomes are written with a range of different levels of ability, whenever learning outcomes which draw on higher cognitive ability (e.g. evaluate, relate) are applicable, other learning outcomes drawing on lower cognitive ability (e.g. state, describe) are not listed. **The learning outcomes for the extension topics are underlined**.

This provides a basic framework upon which the learning and teaching activities can be developed. For general principles and examples of learning and teaching strategies, please refer to Chapter 4. Students are expected to demonstrate the whole range of cognitive abilities and use these learning outcomes as the basis for self-directed learning. Teachers can also use these learning outcomes to set assessment tasks for monitoring the progress of learning.

(4) Suggested learning and teaching activities

This column of the table suggests activities that can be provided for students to enable them to achieve the learning outcomes. The list includes a wide range of activities, such as discussion, debate, practical work, investigations, information searching and projects. It should be seen as a guide for teachers rather than as an exhaustive or mandatory list. Teachers should exercise their professional judgment in selecting activities to meet the interests and abilities of their students. Where possible, the activities should be framed in the context of students' own experience, to enable them to make connections with scientific knowledge, society and the environment around them. Students will then be well equipped to apply scientific concepts,

theories, processes, and values to situations in which they have to investigate and solve everyday problems. Teachers may refer to Chapter 4 for general principles and examples of learning and teaching strategies.

(5) Curriculum Emphases

This part includes Science and Technology for Society and Environment, the Nature of Science. It outlines how the learning and teaching of the relevant topics in the Unit could help enhance students' understanding of the how science and technology influence the society and environment and the nature of science.

For the other curriculum emphasis, Scientific Inquiry, teachers may refer to the **S** skills and practices/processes listed in the learning outcomes in each Unit as well as those skills, practices and process for scientific investigation listed in Unit XIII.

I. Cells (12 hours)

Overview

Cells are the fundamental units of life. Organisms are built up of these fundamental units which function as an integrated whole. In this Unit, students will study the structural organisation of a cell, and relate the structures of cells, cell organelles and membranes to their functions. Studying the structure-function relationship will lay the foundation for students to understand and relate cellular processes to the essential life processes of organisms.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Cells and cellular organisation	**K 1** recognise that there are different types of cells, tissues, organs, and systems in multicellular organisms to carry out different functions **K 2** recognise the sub-cellular structures (cell membrane, nucleus, vacuole, cell wall, rough endoplasmic reticulum and smooth endoplasmic reticulum, Golgi body, mitochondrion, chloroplast) **K 3** describe the functions of the above sub-cellular structures **K 4** compare the structure of prokaryotic cells and eukaryotic cells **S 1** prepare temporary mounts of plant tissue and animal tissue **S 2** use a light microscope for observation using different magnifications	• Conduct a project to explore the contribution of the development of the microscope to the understanding of cells. • Examine photomicrographs or prepared slides of different types of cells and tissues in multicellular organisms. • Prepare temporary mounts of plant tissue (e.g. leaf epidermis, pollen grains, banana tissues) and animal tissue (e.g. ox cornea, pig liver) for examination under a light microscope.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	S 3 identify the sub-cellular structures from photomicrographs, electron micrographs and biological drawings of typical plant cells and animal cells **S 4** calculate the magnification of images and sizes of cell structures and sub-cellular structures shown in photomicrographs, electron micrographs, and biological drawings	• Examine electron micrographs of prokaryotic, eukaryotic cells and sub-cellular structures.
Structure, functions, and properties of the cell membrane	**K 5** explain the fluid mosaic model of membrane structure with reference to the arrangement of phospholipids and membrane proteins **K 6** relate the arrangement of different membrane proteins (carrier proteins, channel proteins, membrane enzymes, cell surface antigens, and cell surface receptors) to their functions **K 7** relate the properties and functions of the cell membrane to its structure **S 5** design and perform an investigation on membrane permeability	• Make a physical model to represent the structure of the cell membrane. • Read articles about the development of models of membrane structure. • Design and perform investigations to study the effect of temperature and organic solvents on the permeability of cell membranes.
Transport across the cell membrane	**K 8** explain the processes of transport across the cell membrane (simple diffusion, facilitated diffusion, osmosis and active transport) **K 9** account for the movement of water across the cell membrane in terms of water potential	• Watch animations or video clips about diffusion, osmosis, active transport, endocytosis and exocytosis.

Topics Students should learn	Learning outcomes **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	Suggested learning and teaching activities
	K 10 apply the concept of osmosis to explain lysis and shrinkage of animal cells, turgor and plasmolysis of plant cells **S 6** plot and interpret graphs for determining the water potential of some plant tissues bathed in solutions of different water potentials (hypotonic, isotonic, and hypertonic solutions) **S 7** design and perform an investigation on osmosis **K 11** state that substances can move in or out of cell by endocytosis or exocytosis	• Design and perform an investigation to study the effect of different shapes and sizes on the rate of diffusion of dye in agar blocks. • Perform practical work to study osmosis at cellular, tissue or organ levels using live specimens (e.g. potatoes, grapes, decalcified eggs, red onions, *Elodea*). • Perform practical work to study osmosis using non-living materials (e.g. dialysis tubing).

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the applications of biological knowledge of cells in society;
- the development of microscopic technology, computing technology and image analysing technology led to the advancement of biological knowledge;

Nature of Science

- the dynamic nature of biological knowledge (e.g. the understanding of cell membrane and sub-cellular organelles);
- the contributions of various scientists (e.g. Robert Hooke and Theodor Schwann) to developments in biology;
- the biological knowledge and theories are developed through observations, hypotheses, experimentations and analyses (e.g. fluid mosaic model of cell membrane structure)
- the uses and limitations of scientific models (e.g. the fluid mosaic model of membrane structure)

II. Cellular Energetics (15 hours)

Overview

Cells require energy to support their various functions. Cellular energetics refers to the study of the processes and mechanisms by which cells generate, store, and utilise energy. In this Unit, students will learn about metabolism, the properties and actions of enzymes, and the roles of enzymes in metabolism. Besides, they will learn about respiration and photosynthesis as examples of catabolic processes and anabolic processes in cells respectively. In these parts, students should focus on the major concepts related to energy transformation, for example, energy capture, energy release and energy utilisation; and chemical transformation, for example, breaking down and building up processes, in respiration and photosynthesis.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Metabolism	**K 1** compare catabolic processes and anabolic processes	
Enzymes and enzymatic reactions	**K 2** state the properties of enzymes **K 3** explain the roles of enzymes in metabolism **K 4** explain the action of enzymes **K 5** explain the effect of temperature and substrate concentration on enzyme activity	• Perform practical work to demonstrate the breaking down action of enzymes using catalase or amylase. • Perform practical work to demonstrate the building-up action of enzymes using starch synthases and glucose-1-phosphate.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K 6 describe the effect of pH, enzyme concentration, and inhibitors[1] on enzyme activity **S 1** determine the enzyme activity in terms of the rate of formation of products or the rate of disappearance of substrates **S 2** plot and interpret graphs showing the effect of different factors on the rate of enzymatic reactions **K 7** state the application of enzymes **S 3** design and perform investigations on the effect of different factors on enzyme activity	• Design and perform investigations to study the effects of temperature, pH, substrate concentration, enzyme concentration, or inhibitors on the activities of enzymes. • Design and perform investigations to study the action of enzymes in some commercial applications of enzymes (e.g. protease and amylase in bioactive washing powder, cellulase and pectinase in the production of fruit juice, lactase in the production of lactose-free milk). • Perform practical work to measure the progress of enzyme-catalysed reactions that involve colour changes using a colorimeter or a mobile device with relevant application. • Conduct a project on the commercial or industrial applications of enzymes (e.g. medical uses, agricultural uses, biosensors, food production).

[1] Different types of inhibitors are not the focus of learning and assessment.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Respiration: an example of a catabolic process	**K 8** state the significance of respiration **K 9** state that respiration is a catabolic process in cells in which glucose is broken down through a series of enzyme-catalysed reactions to release energy in the form of ATP **K10** state that ATP is the immediate source of energy for biological processes **K11** recognise that some energy is converted to heat during respiration **K12** state that glycolysis[2] involves the breakdown of glucose to pyruvate, with production of ATP and electron carriers in the cytoplasm **K13** outline the major steps in the aerobic pathway (conversion of pyruvate to a 2-C compound with the production of carbon dioxide and electron carriers in the matrix of mitochondrion; Krebs cycle[3] in which the 2-C compound is combined with a 4-C compound to form a 6-C compound, then two carbon dioxide is released and the 4-C compound is recycled through a cyclic series of reactions with the production of ATP and electron	• Watch animations showing the processes of aerobic respiration and anaerobic respiration to understand the catabolic processes. • Examine the electron micrographs of mitochondria. • Design and perform investigations to study the rate of aerobic respiration in organisms (e.g. germinating seeds, mealworms, and grasshoppers). • Perform practical work to show the heat production during respiration in organisms (e.g. germinating seeds, mealworms, and grasshoppers). • Design and perform investigations to study the rate of anaerobic respiration in yeast.

[2] Refer to the schematic diagram in Appendix 1. (TBC)
[3] Refer to the schematic diagram in Appendix 1. (TBC)

Topics Students should learn	Learning outcomes **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	Suggested learning and teaching activities
	carriers in the matrix of mitochondrion; and oxidative phosphorylation[4] which produces ATP from the electron carriers on the inner membrane of the mitochondrion) **K14** relate the structure of the mitochondrion to its function in respiration **S 4** identify the structures of mitochondria in electron micrographs **K15** outline the major steps (glycolysis and formation of lactic acid) of anaerobic respiration in human skeletal muscle **K16** compare aerobic respiration and anaerobic respiration in humans **K17** outline the major steps (glycolysis and formation of ethanol) of anaerobic respiration in yeasts **S 5** design and perform investigations on the rate of respiration in organisms	
Photosynthesis: an example of an anabolic process	**K18** state the significance of photosynthesis **K19** state that photosynthesis is an anabolic process in which large biomolecules are synthesised from smaller molecules like carbon dioxide and water using light energy	• Watch animations showing the processes of photochemical reactions and the Calvin cycle to understand the anabolic processes. • Examine electron micrographs of chloroplasts.

[4] Refer to the schematic diagram in Appendix 1. (TBC)

Topics Students should learn	Learning outcomes **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	Suggested learning and teaching activities
	K20 state that photosynthesis consists of two main stages (photochemical reactions and the Calvin cycle) and state the sites where these two stages occur **K21** recognise that light energy captured by chlorophyll is used to split water in the photochemical reactions, and also converted to chemical energy for the next stage **K22** outline the major steps (light absorption[5], photolysis of water for the generation of ATP and temporary electron carriers, and the release of oxygen as a byproduct) of photochemical reactions[6] which occur in the thylakoids of chloroplasts **K23** outline the major steps (carbon dioxide combines with a 5-C compound for the formation of two 3-C compounds; the 3-C compound is converted to a 3-C sugar; some 3-C sugar will go through the cyclic sequence of reactions to regenerate the 5-C compound and to produce temporary electron carriers; some 3-C sugars are then converted into other biomolecules) of the Calvin Cycle[7] which occur in the stroma of chloroplasts	

[5] Photosystem is not the focus of learning and assessment.
[6] Refer to the schematic diagram in Appendix 2. (TBC)
[7] Refer to the schematic diagram in Appendix 2. (TBC)

Topics Students should learn	Learning outcomes **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	Suggested learning and teaching activities
	K24 relate the structure of a chloroplast to its functions in photosynthesis **S 6** identify the structures of chloroplasts in electron micrographs **K25** compare respiration and photosynthesis	

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the development of microscopic technology, computing technology, and image-analyzing technology led to the advancement of biological knowledge;
- the applications of enzymes in the society

Nature of Science

- the dynamic nature of biological knowledge (e.g. the understanding of cellular processes);
- the contributions of various scientists (e.g. Melvin Calvin, Sir Hans Krebs) to developments in biology;

- the biological knowledge and theories are developed through observations, hypotheses, experimentations, and analyses (e.g. fluid mosaic model of cell membrane structure)
- the lock and key hypothesis for explaining the action of enzymes.

III. Life Processes in Plants (18 hours)

Overview

Plants require light, oxygen, water and food to survive. In this unit, students will study various life processes in plant, including nutrition, gas exchange, transport and support, in order to understand how plants meet their basic needs. As autotrophs, plants make organic substances from inorganic compounds. Through the gas exchange, plants obtain the gases necessary for photosynthesis and respiration from the air. Water and minerals are absorbed in the roots and then transported to the leaves for photosynthesis or other parts of the plants for other metabolic processes. The organic substances produced in the leaves are transported to the other parts of the plants to provide energy for metabolic reactions and growth. In addition to the major concepts underlying these life processes, students will also study the structure-function relationships of specialised cells and tissues for performing various physiological functions within the plant.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Nutrition in plants[8]	**K1** recognise the significance of plants as autotrophs **K2** explain the ecological significance of photosynthesis in terms of material flow and energy flow **K3** explain the effects of light intensity and carbon dioxide concentration on the rate of photosynthesis	• Design and perform investigations to study the effects of changes in environmental factors (e.g. light intensity and carbon dioxide concentration) on the rate of photosynthesis.

[8] Confine to terrestrial dicotyledonous plants only.

Topics Students should learn	Learning outcomes **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	Suggested learning and teaching activities
	S1 design and perform investigations on the effects of light intensity and carbon dioxide concentration on the rate of photosynthesis **S2** plot and interpret graphs showing the effects of light intensity and carbon dioxide concentration on the rate of photosynthesis **K4** state the mineral requirements (nitrate, phosphate, potassium ions) of plants **K5** state the functions of water in plants **K6** relate the structure of root hair cells to their functions in the absorption of water and minerals **S3** identify the structures of the cross-section of a young root in photomicrographs and biological drawings **K7** describe the process of water absorption into root hair cells by osmosis **K8** describe the process of mineral absorption into root hair cells by diffusion and active transport	• Examine the external and internal structures of the roots of young seedlings using live specimens or prepared slides. • Design and perform investigations to study the requirement of minerals on plant growth using potted plants.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Gas exchange in plants[9]	**K9** state the sites of gas exchange in plants **K10** describe the process of gas exchange in a leaf **K11** relate the structure of a leaf[10] to its functions in photosynthesis and gas exchange **S4** identify the structures of the cross-section of a leaf in micrographs and biological drawings **K12** explain the effects of light intensity on gas exchange in plants **S5** interpret graphs showing the rate of uptake or release of carbon dioxide and oxygen of a plant under different light intensity	• Examine the external structure and internal structure of a leaf using models, photomicrographs, prepared slides, or live specimens. • Design and perform an investigation to compare the relative abundance of stomata on both sides of a leaf. • Design and perform investigations to study the effects of light intensity on gas exchange in plants using hydrogencarbonate indicator solution, or data loggers with an oxygen sensor or a carbon dioxide sensor.
Transport of substances in plants[11]	**K13** state the sites of transpiration in plants **K14** describe the process of transpiration in a leaf **K15** describe the movement of water across cells in the leaf through the cell wall and the cell membrane	• Perform practical work to demonstrate the occurrence of transpiration. • Perform practical work to trace the uptake of water in herbaceous plants using dye solution.

[9] Confine to terrestrial dicotyledonous plants only.
[10] Confine to terrestrial dicotyledonous leaves only.
[11] Confine to terrestrial dicotyledonous plants only.

Topics Students should learn	Learning outcomes K Knowledge and understanding S Skills and processes/practices Students should be able to	Suggested learning and teaching activities
	K16 state that transpiration creates a transpiration pull that helps the transport of water and dissolved minerals to the upper parts of a plant **K17** describe the path of water transport from the root to the leaf through the xylem **K18** describe the movement of water across cells in the root through the cell wall and the cell membrane **K19** relate the structure of xylem to its function in the transport of water **K20** explain the structural features of leaves in reducing water loss **K21** explain the effects of environmental factors (light intensity, temperature, humidity and air movement) on the rate of transpiration **S6** design and perform investigations on the rate of transpiration **S7** plot and interpret graphs showing the effects of environmental factors on the rate of transpiration **K22** describe the path of translocation of organic nutrients in the phloem between different parts of a plant (photosynthetic tissues, storage organs, and growth regions)	• Examine the cross-section of the stem of a young plant using temporary mounts or prepared slides. • Design and perform investigations to study the effects of stomatal density or different environmental factors on the rate of transpiration (e.g. using a potometer). • Read articles about scientists' works for studying the translocation of organic nutrients (e.g. using a radioactive tracer, aphids, and ringing experiments). • Search for information about some agricultural practices related to the translocation of organic nutrients (e.g. stem girdling).

Topics Students should learn	Learning outcomes K Knowledge and understanding S Skills and processes/practices Students should be able to	Suggested learning and teaching activities
	K23 relate the structure of phloem (sieve tube elements and companion cells) to its function of transporting organic nutrients in plants S8 identify the vascular tissues in the cross-section and longitudinal section of a stem in photomicrographs and biological drawings S9 identify the vascular tissues in the cross-section of a root and a leaf in photomicrographs and biological drawings	
Support in plants[12]	K24 explain the significance of support in plants K25 describe the means of support in plants (cell turgidity, rigidity of xylem) K26 compare the means of support in herbaceous plants and woody plants	• Examine the cross-section of a woody stem using prepared slides or photomicrographs.

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the applications of biological knowledge in agricultural practices;

[12] Confine to terrestrial dicotyledonous plants only.

- the ecological significant of photosynthesis

Nature of Science

- the dynamic nature of biological knowledge (e.g. the understanding of the cell membrane and subcellular organelles);
- the biological knowledge and theories are developed through observations, hypotheses, experimentations and analyses (e.g. the translocation of organic nutrient in plants)
- the limitations of scientific activity (e.g. investigations on various physiological processes in plants)

IV. Human Physiology I (36 hours)

Overview

Human physiology is the study of the human body's function. In this Unit, students will learn about the functions of different body systems, including the digestive system, the respiratory system, the circulatory system, the urinary system, and the musculoskeletal system in humans. They will study how the organisation of specialised cells, tissues, and organs in these systems works to obtain oxygen, water and food, remove waste to maintain life, and facilitate movement of the body. The study of nutrition and gas exchange in humans will extend from students' learning of relevant topics in the Science (S1-3) curriculum at the junior secondary level.

Besides, students will learn about how humans respond to changes in their external and internal environments. In the junior secondary level, students have studied how humans detect external environment through receptors in the sense organs, eyes and ears, in the Science (S1-3) curriculum. Building on these learning, students will learn about the coordinating roles played by the nervous and hormonal systems in bringing about appropriate responses in humans. The coordination through nervous impulse transmission and hormones to the respective effectors, like muscles and glands, will also be studied.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Nutrition in humans	**K1** recognise the importance of a balanced diet **S1** evaluate the nutritional and energy intake from the nutrition label of some packaged food with reference to data of some nutrient reference values provided	• Examine the nutrition labels on different brands of packaged food and compare the nutritional values of these foods.

Topics Students should learn	Learning outcomes **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	Suggested learning and teaching activities
	S2 identify the main regions of the human alimentary canal and the related organs (mouth cavity, salivary glands, oesophagus, stomach, duodenum, pancreas, gall bladder, liver, ileum, colon, rectum, and anus) as shown in photographs and biological drawings **K2** state the functions of the above main regions and organs in relation to ingestion, digestion, absorption, assimilation, and egestion **K3** state the significance of mechanical and chemical digestion **K4** state the significance of peristalsis in the alimentary canal **K5** describe the digestion and absorption processes of food (carbohydrates, proteins and lipids) in various parts of the alimentary canal **S3** design and perform investigations to study the action of digestive enzymes **K6** explain the structure of the small intestine and the villi in relation to their functions in food absorption **S4** identify the structures of the small intestine in photomicrographs, electron micrographs, and biological drawings	• Examine the alimentary canal and its related organs of a dissected mammal or a human torso. • Perform practical work to study the effect of bile salt on oil. • Design and perform investigations to study the action of digestive enzymes (e.g. amylase on starch-agar plate, lactase on lactose, protease on milk-agar plate or egg white, lipase on lipids). • Examine the structure of the small intestine using photomicrographs, electron micrographs, or prepared slides. • Perform practical work to simulate digestion and absorption in the alimentary canal using dialysis tubing.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K7 describe the routes of the transport of absorbed food and their fates in cells and tissues during assimilation **K8** outline the function of the liver in the metabolism of excess glucose and amino acids **K9** state the function of the liver in the detoxification of absorbed harmful substances	
Gas exchange in humans	**K10** recognise the need for a breathing system in humans **S5** identify the main parts of the human breathing system (nasal cavity, trachea, bronchi, bronchioles, lungs, air sacs, rib cage and diaphragm) as shown in photographs and biological drawings **K11** relate the structure of the above parts of the breathing system to their functions in breathing and gas exchange **S6** identify the structures of the trachea and the air sacs in photomicrographs and biological drawings **K12** describe the mechanism of ventilation (inhalation and exhalation) **S7** interpret graphs showing the change in air pressure and volume of the lungs during inhalation and exhalation **K13** describe the process of gas exchange in the air sacs	• Examine the breathing system of a dissected mammal or a human torso. • Examine a pig's lungs. • Examine the structure of the trachea and air sacs using a prepared slide or photomicrograph. • Discuss how gas exchange in humans is affected by some respiratory diseases. • Search for information about the health hazards of electronic cigarettes. • Search for information about some common air pollutants and their effects on the breathing system.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K14 relate the structure of a red blood cell to its function in the transport of respiratory gases in blood **K15** state the major forms of transport of respiratory gases in blood **K16** explain how smoking[13] affects gas exchange **K17** recognise that air pollutants affect the breathing system	
Transport in humans	**K18** recognise the need for a transport system in humans	
Blood circulatory system	**K19** state the main components of the blood circulatory system (heart, blood vessels and blood) **K20** state the composition and functions of blood **S8** identify red blood cells, white blood cells and platelets in the photomicrographs of human blood smear **K21** state the functions of the structures of the heart and its associated blood vessels **S9** identify the structures of the heart and its associated blood vessels as shown in specimens, photographs and biological drawings **K22** outline the pathway of double circulation	• Examine the components of blood using prepared slides or photomicrographs. • Search for information about the development of artificial blood. • Examine the structure of the heart using a heart model or a dissected pig's heart. • Measure blood pressure and heart rate using appropriate instruments (e.g. blood pressure monitor). • Search for information about the development of artificial heart and artificial heart valves.

[13] Confined to the effects of tar and carbon monoxide

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K23 compare the structure and functions of an artery, a vein, and a capillary **S10** identify the structures of an artery, a vein and a capillary in photomicrographs or biological drawings **K24** explain the change in blood pressure along different blood vessels **S11** interpret graph showing the change of blood pressure along different types of blood vessels **K25** state the significance of the low rate of blood flow in capillaries **K26** outline the risk factors and prevention methods of some cardiovascular diseases (coronary heart disease, stroke) **K27** explain the formation of tissue fluid **K28** describe the exchange of materials between tissue fluid and body cells at the capillary bed **K29** explain the return of tissue fluid	• Examine the structure of an artery and a vein using prepared slides or photomicrographs. • Read the article about William Harvey's explanation of the function of valves. • Search for information about the treatments (e.g. angioplasty, coronary artery bypass graft) of some cardiovascular diseases. • Examine the capillary flow in a fish's tail fin or frog's web. • Construct a model to simulate the pumping action of the heart and blood circulation. • Read articles about the discovery of blood circulation in humans by scientists (e.g. William Harvey).
Lymphatic system	**K30** state the main components of the lymphatic system (lymph vessels, lymph nodes, and lymph) and their functions **K31** describe the formation of lymph and its return to the blood circulation	• Examine the structure of lymph vessels using prepared slides or photomicrographs. • Search for information about the benefits of an active lifestyle to the circulatory system.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
		• Search for information about the phenomenon of deep vein thrombosis resulting from prolonged immobility during long-distance travel.
Excretion in humans	**K32** state the significance of excretion to organisms **K33** state the human excretory organs (skin, lungs and kidneys) and the respective waste substances to be excreted **S12** identify the main parts (kidneys, ureters, urinary bladder, urethra) of the human urinary system as shown in photographs and biological drawings **K34** state the functions of the above parts in relation to excretion **S13** identify the structures of a nephron and its associated blood vessels (glomerulus, the afferent arteriole and the efferent arteriole, Bowman's capsule, first coiled tubule, loop of Henle, second coiled tubule, collecting duct) **K35** describe and explain the processes of ultrafiltration and selective reabsorption in urine formation with reference to the structure of a nephron and its associated blood vessels	• Examine the urinary system of a dissected mammal or a human torso. • Examine the structure of the kidney using a kidney model or a dissected mammalian kidney. • Search for information about the working principle of the dialysis treatment.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Movement in humans	**K36** state the roles of skeleton, skeletal muscles, tendons, ligaments and joints in movement **K37** relate the structure of a synovial joint to its function **K38** compare the degree of movement between a hinge joint and a ball-and-socket joint **S14** identify the types of joints (a hinge joint and a ball-and-socket joint) in X-ray radiographs **K39** describe the action of opposing muscle pairs in movement	• Examine a model of the human skeleton and a model of the human arm. • Use models to demonstrate the degree of movement of a hinge joint and a ball-and-socket joint. • Examine X-ray radiographs of bones and joints. • Use models to demonstrate how the muscles could move the limbs. • Perform practical work to dissect a chicken leg to examine the muscle fibres, joints, ligaments and tendons.
Coordinating system in humans	**K40** state the significance of irritability to humans **K41** state the need of coordinating systems in humans	

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Nervous coordination in humans	**K42** state the roles of receptors, a coordination centre and effectors in nervous coordination **K43** state that a neurone is a specialised cell for the transmission of nerve impulse **K44** distinguish different types of neurones (sensory neurone, interneurone and motor neurone) in terms of their structures and functions **K45** recognise that synapses are junctions between neurones, between neurones and receptor cells, or between neurones and effector cells **K46** describe the structure of a synapse **K47** describe the process of transmission of nerve impulses across a synapse **K48** state the significance of synapses **S15** identify the main parts (brain, spinal cord) of the central nervous system and the main parts (cranial nerves, spinal nerves) of the peripheral nervous system as shown in photographs and biological drawings **K49** describe how the central nervous system is protected by the cranium, the vertebral column and the cerebrospinal fluid	• Examine electron micrographs of synapses. • Perform practical work to observe the contraction of a teased muscle from the leg of a pithed frog. • Examine a model of the human brain. • Perform practical work to demonstrate a reflex action (e.g. a knee jerk reflex, a pupil reflex). • Design and construct a model to simulate a reflex action (e.g. a withdrawal reflex). • Search for information about the use of rehabilitation robotics technologies in helping patients with stroke or damage in the central nervous system to restore their motor skills.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K50 describe the function of spinal cord in coordinating body functions **S16** identify the main parts (cerebrum, cerebellum, medulla oblongata) of the brain **K51** describe their functions of the above parts in coordinating body functions **K52** state the functions of the sensory, association and motor areas of the cerebral cortex in coordinating body functions **K53** state that the spinal cord is the coordination centre for spinal reflexes **K54** describe a simple reflex arc using the withdrawal reflex as an example **K55** state the significance of reflex actions **S17** draw the reflex arc of a withdrawal reflex **K56** state the nature of voluntary actions **K57** identify the key differences between reflex actions and voluntary actions	
Hormonal coordination in humans	**K58** state that hormonal coordination involves hormones produced by endocrine glands to affect the activities of one or more specific target organs	

Topics Students should learn	Learning outcomes **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	Suggested learning and teaching activities
	K59 outline the mechanism of hormonal action in terms of internal stimuli, coordination system (endocrine gland and hormones), target organs and responses using regulation of blood glucose as an example **K60** compare hormonal coordination and nervous coordination	

*(*Note: The underlined text represents the content of the extension part)*

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the applications of biological knowledge in society (e.g. dietary requirement, balanced diet)
- the applications of biological knowledge in the development of artificial blood, artificial heart and artificial heart valves;
- the phenomenon of deep vein thrombosis resulting from prolonged immobility during long-distance travel
- the application and working principle of the dialysis machine
- the application of rehabilitation robotics technologies in helping patients with stroke or damage in the central nervous system to restore their motor skills

Nature of Science

- the dynamic nature of biological knowledge (e.g. the discovery of the function of heart and blood circulation in humans);
- the biological knowledge and theories are developed through observations, hypotheses, experimentations and analyses (e.g. the discovery of the function of heart and blood circulation by William Harvey)
- the limitations of scientific activity (e.g. investigations on various human physiological processes)

V. Human Physiology II (15 hours)

Overview

In this Unit, students will focus on how humans regulate the internal body environment to maintain a relatively stable condition for proper body functioning. Students will develop a deeper understanding of the physiological processes in humans that regulate and control the changes in some parameters of the internal environment of the body, including blood glucose level, body temperature, water content, and gas content in blood. Lastly, students will develop an understanding of the interaction of various regulatory processes through studying a case "human physiology for exercises".

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Homeostasis	**K1** state the significance of homeostasis to organisms **K2** recognise that some parameters of the internal environment (glucose level in blood, body temperature, water content and gas content in blood) are under homeostatic regulation **K3** explain the principle of negative feedback mechanism and state its significance in homeostatic regulation	• Construct a flow chart to illustrate the feedback mechanism using an appropriate example of homeostatic regulation.
• Regulation of blood glucose level	**K4** state the significance of regulation of blood glucose level **K5** outline the regulation of blood glucose level by the actions of insulin and glucagon	• Search for information about the physiological consequences of hormonal

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K6 state the causes of Type I diabetes and Type II diabetes	imbalance (e.g. insulin) and the related remedies. • Search for information about the development of devices for monitoring blood glucose level. • Conduct a project on the causes and treatment of type I diabetes and type II diabetes.
• Regulation of body temperature	**K7** state the significance of regulation of body temperature **K8** state that body temperature is regulated through the balance between heat loss and heat gain **K9** explain how the responses (sweating, vasodilation, vasoconstriction, shivering) of the effectors affect heat loss or heat gain of the body **K10** describe the nervous control in thermoregulation that involves thermoreceptors, the thermoregulatory centre and various effectors to promote heat loss or heat gain of the body	• Construct a flow chart to show the mechanism of temperature regulation. • Examine prepared slides or photomicrographs to identify the features of mammalian skin that are related to temperature regulation. • Search for information about the warning signs and symptoms resulted from the failure of thermoregulation (hyperthermia or hypothermia) and the necessary actions to be taken.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
• Regulation of water content	**K11** state the significance of regulation of water content **K12** describe the roles of the osmoreceptors in the hypothalamus, posterior pituitary, antidiuretic hormone (ADH), second coiled tubule and collecting duct in osmoregulation	• Watch animations showing the process of osmoregulation.
• Regulation of gas content in blood	**K13** state the significance of regulation of gas content in blood **K14** describe the roles of chemoreceptors, coordination centre (respiratory centre in the medulla oblongata) and effectors (diaphragm and intercostal muscles) in the nervous control of the rate and depth of breathing **K15** recognise that the sinoatrial node (SA node) is the natural pacemaker of the heart **K16** outline the major stages during the cardiac cycle **K17** state that the cardiac output is determined by the stroke volume and the heart rate **K18** describe the roles of chemoreceptors, coordination centre (cardiovascular centre in the medulla oblongata) and effectors (cardiac muscle) in the nervous control of cardiac output **K19** describe the roles of the adrenal glands and adrenaline in the hormonal control of cardiac output	• Search for information about the use of electrocardiograms to record the activity of the heart. • Search for information about the working principle of an automated external defibrillator (AED) and how to operate it. • Search for information about the working principle of the artificial pacemaker. • Design and perform investigations to study the effect of chemicals on the heart rate of *Daphnia*.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Case study: human physiology for exercise	**K20** explain the significance of the increase in blood supply to skeletal muscles during exercise **K21** state that lactic acid built up in muscles and blood during vigorous exercise causes an oxygen debt **K22** outline how the oxygen debt is repaid for the removal of lactic acid after vigorous exercise **K23** explain the cardiorespiratory responses (breathing rate and depth, cardiac output) in humans during and after exercise **K24** outline the thermoregulatory process and osmoregulatory process of a runner during a marathon under different environmental conditions (ambient temperature, relative humidity) **K25** describe the biological principles of carbohydrate loading for increasing the performance of a runner in a marathon	• Search for information about the training of a marathon runner. • Search for information about the principle of carbohydrate loading. • Design and perform investigations to study the changes in heart rate and breathing rate before and after exercise using data loggers or other methods.

*(*Note: The underlined text represents the content of the extension part)*

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the application of biological knowledge in understanding the causes and the treatment of diabetes

- the application of biological knowledge in preventing the occurence of undesirable body conditions (e.g. hyperthermia or hypothermia) and the emergent remedies
- the application of biological knowledge in the development of artificial pacemaker and automated external defibrillator (AED)
- the application of biological knowledge in enhancing the performance of athletes

Nature of Science

- the dynamic nature of biological knowledge in human physiology
- the biological knowledge and theories are developed through observations, hypotheses, experimentations, and analysis
- the limitations of scientific activity (e.g. investigations on various human physiological processes)

VI. Organisms and their environment (16 hours)

Overview

Organisms are an integral part of the environment. Their ways of living are closely related to the environment where they live. In this Unit, building on the overarching concepts of the ecosystem as a dynamic system, students will use woodland as an example to learn about the interactions of organisms with both the abiotic (non-living) components, such as air, water, and soil, and the biotic (living) components, such as other organisms living in the same habitat. Then the energy flow and cycling of materials within an ecosystem will be studied in a wider context. Organisms living in a habitat usually have specialised structures and behaviors that allow them to obtain the resources they need to survive and reproduce from their environment. In turn, the activities of organisms can modify the environment in which they live. Changes in the environment will then affect the inhabitance of other organisms. This brings out the concept of ecological succession. Understanding the dynamic interplay between organisms and the environment is crucial for comprehending the natural world and paving the way to making informed decisions about environmental management and conservation in Unit 12.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Ecosystem	**K1** recognise the levels of organisation from an individual, a population, a community to an ecosystem **K2** recognise the characteristics and ecological significance of some major ecosystems in Hong Kong (woodland, freshwater stream, rocky shore and mangrove)	• Watch video clips on different major ecosystems (woodland, freshwater stream, rocky shore and mangrove) in Hong Kong. • Conduct an ecological study to one major ecosystem in Hong Kong.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K3 outline the components (abiotic factors and biotic factors) and interactions (interactions between organisms, one-way flow of energy and cyclic flow of matters) in an ecosystem	• Design and make an ecosphere or a bottle garden.
Interaction in a woodland ecosystem[14]	**K4** recognise the existence of different types of woodland (Fung Shui woods, secondary forests and plantation forests) in Hong Kong **K5** identify the abiotic factors (light intensity, rainfall, wind speed, temperature, relative humidity and soil) of a woodland **K6** recognise the biotic factors of a woodland **K7** identify and describe the roles of producers, consumers and decomposers in a woodland **S1** construct and interpret food chains and food webs showing the feeding relationships of organisms in a woodland **S2** use appropriate sampling methods (quadrats, belt transects and line transects) to study the distribution and abundance of organisms in a woodland	• Use suitable equipment to measure the abiotic factors (e.g. light intensity, wind speed, temperature, relative humidity and soil) of a woodland. • Visit a local woodland and identify the biotic factors in a woodland and their ecological roles. • Watch videos showing the ecological relationships (e.g. predation, competition, commensalism, mutualism and parasitism) of organisms in an ecosystem. • Construct and interpret food chains and food webs.

[14] Woodland is used as an example for the learning and teaching of ecological concepts in context. Students should be able to transfer the knowledge about these concepts to other ecosystems based on the information and data given.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K8 describe the different types of ecological relationship (predation, interspecific competition and intraspecific competition, commensalism, mutualism and parasitism) between organisms, with examples in a woodland **K9** explain that interspecific competition is due to overlapping of niches **K10** give examples to illustrate that abiotic factors and interaction between different biotic factors can influence the composition of a community **S3** interpret data from investigations on the effect of abiotic factors and biotic factors on the distribution and abundance of living organisms in a woodland	• Examine some lichen specimens using light microscope or photomicrographs. • Examine some parasitic plants (e.g. dodder). • Use suitable methods (e.g. quadrats, belt transects and line transects) to assess the distribution and abundance of sessile or slow-moving organisms in an area. • Use suitable method (e.g. line transects) to assess the distribution and abundance of moving organisms (e.g. butterfly and dragonfly) in an area.
Energy flow and material cycling	**K11** state the ecological significance of photosynthesis in energy flow **S4** sketch and interpret the pyramid of numbers, pyramid of biomass and pyramid of energy for illustrating the energy flow between different trophic levels **K12** explain the energy loss within a trophic level and the energy **loss between trophic levels**	• Construct and interpret the pyramid of numbers, pyramid of biomass and pyramid of energy for the food chains in different habitats (e.g. a woodland, a freshwater stream, a rocky shore). • Construct a diagram of a carbon cycle. • Construct a diagram of a nitrogen cycle. • Examine the root nodules in some legumes.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K13 explain the limitations of the use of pyramid of numbers and pyramid of biomass to represent the energy flow **S5** calculate the efficiency of energy transfer between trophic levels **K14** describe the key processes in a carbon cycle **K15** describe the key processes in a nitrogen cycle **K16** state the significance of the carbon cycle and nitrogen cycle to the ecosystem	• Design and make an aquaponics system, and construct diagrams of the material cycling involved in the system.
Ecological succession	**K17** state that ecological succession is a process of changes in the composition of a biological community over time **K18** recognise that pioneer species will gradually be replaced by other species **K19** recognise that the community in some environments may reach a climax community **S6** interpret data about the changes in structure of a community through ecological succession	• Examine photographs showing the changes of a woodland after a hill fire over a certain period of time to study the ecological succession taken place.

*(*Note: The underlined text represents the extension part)*

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the application of biological knowledge has enhance our understanding of the interactions different components in an ecosystem

Nature of Science

- the biological knowledge and theories are developed through observations, hypotheses, experimentations, and analyses
- the limitation of scientific activity (e.g. investigations on ecosystems)
- the limitation of science (e.g. the use of pyramid of number and pyramid of biomass to represent they energy flow among living organisms in an ecosystem)
- the possible bias in recording, reporting and interpreting data (e.g. investigations on the distribution of organisms in a habitat)

VII. Continuity of Life (24 hours)

Overview

Continuity of life is one of the vital functions of living organisms, in which organisms produce offspring to perpetuate the species.

In this Unit, students will learn about the cell division processes through which a single parent cell is divided into two or more daughter cells. Students will then learn about the different methods of reproducing offspring used by different organisms, ranging from single-celled organisms to flowering plants and humans. Some organisms carry out asexual reproduction involving mitotic cell division with the production of offspring, which are genetically identical among themselves and their parents. Most organisms reproduce sexually. Sexual reproduction involves the production of male and female gametes, which are formed by meiotic cell division. The fusion of gametes leads to the formation of a zygote, which develops into an embryo. The offspring thus produced are genetically different. Students will learn about the structures and processes involved in the sexual reproduction of flowering plants and humans. Besides, the germination of a seed into a seedling is used to illustrate the concept of growth and development. Students will also realise the importance of mitotic cell division in bringing about an increase in body size and that of differentiation of cells leading to an increase in body complexity.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Cell cycle and meiotic cell division	**K1** state the three main phases (interphase, mitosis and cytoplasmic division) of a cell cycle **K2** state that cell growth and DNA synthesis take place in the interphase **K3** outline the events in the four stages (prophase, metaphase, anaphase and telophase) of mitosis **K4** state the significance of mitotic cell division in the production of genetically identical cells for growth, repair and asexual reproduction **K5** outline the events in the eight stages of meiotic cell division **K6** state the significance of meiotic cell division in the production of haploid gametes with genetic variations in sexual reproduction **K7** compare mitotic cell division and meiotic cell division	• Observe and identify the different phases of a cell cycle and the different stages of mitosis using prepared slides or photomicrographs. • Prepare temporary mount of root tip squashes (e.g. garlic or onion root meristem) to observe the different phases of a cell cycle and the different stages in mitosis. • Observe and identify the different stages of meiotic cell division using prepared slides or photomicrographs.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Asexual reproduction and sexual reproduction	**K8** recognise the need for reproduction in living organisms **K9** state that asexual reproduction involves mitotic cell division in the production of daughter cells **K10** state that sexual reproduction involves meiotic cell division in the production of haploid gametes and the formation of diploid zygotes by fertilisation **K11** recognise that single-celled organisms (bacteria, amoeba, yeasts) can reproduce asexually by mitotic cell division **K12** recognise that some flowering plants can reproduce asexually by vegetative propagation **K13** outline the process of vegetative propagation using the potato stem tuber as an example **K14** state the advantages and disadvantages of asexual reproduction	• Watch video clips about the asexual reproduction of single-celled organisms (e.g. bacteria, amoeba, yeasts). • Cultivate and examine some organs (e.g. bulb, corm, rhizome or stem tuber) for vegetative propagation of flowering plants. • Search for information on the application of artificial vegetative propagation in horticulture, agriculture and conservation.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Sexual reproduction in flowering plants	**K15** state the reproductive function of the floral parts **S1** identify the structures (petal, stigma, style, ovary, ovule, anther, filament) of a flower in live specimens or biological drawings **K16** state the significance of pollination **K17** recognise there are self-pollination and cross-pollination in plants **K18** compare the structural features of an insect-pollinated flower and a wind-pollinated flower **K19** recognise that a pollen grain carries the male gamete and an ovule contains the female gamete **K20** outline the processes of the germination of pollen grains and fertilisation **K21** state the fate of the floral parts after fertilisation **K22** state the advantages and disadvantages of sexual reproduction in plants **K23** state the significance of seed dispersal and fruit dispersal **K24** recognise the ways of seed dispersal and fruit dispersal (by wind, animal, water and self-dispersal)	• Examine the structural features of an insect-pollinated and a wind-pollinated flower using a dissecting microscope or a hand lens. • Observe photomicrographs or electron micrographs of the pollen grains of an insect-pollinated and a wind-pollinated flower. • Examine *in vitro* pollen germination under a light microscope. • Search for information on the application of artificial pollination in agriculture and conservation. • Watch video clips about different ways of seed dispersal and fruit dispersal. • Observe different seeds and fruits to infer their ways of dispersal.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Seed germination and plant growth	**S2** identify the structures (seed coat, micropyle, embryo, cotyledons) of a dicotyledonous seed in live specimens or biological drawings **K25** state the significance of water, temperature and oxygen to seed germination **K26** describe the process of seed germination and its development into a new plant **S3** design and perform investigations to study the factors affecting seed germination **K27** describe the growth and development of a plant using root tip as an example **K28** recognise that plants grow in length through primary growth and in diameter through secondary growth **K29** discuss the advantages and disadvantages of using different parameters (size, fresh mass, dry mass) to measure the growth in plants **S4** interpret the growth curve of an annual plant	• Design and perform investigations to study seed germination and the growth of young seedlings. • Watch time-lapse video of seed germination. •
Reproduction in humans	**S5** identify the main parts of the male reproductive system and its associated glands (testes, sperm ducts, , prostate gland, urethra , penis) and the main parts of the female reproductive	• Examine the male and female reproductive systems of dissected mammals or a human torso.

Topics Students should learn	Learning outcomes **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	Suggested learning and teaching activities
	system (ovaries, oviducts, uterus, cervix, vagina) as shown in photographs and biological drawings **K30** state the functions of the above parts in relation to reproduction **K31** state the roles of a sperm and an ovum in sexual reproduction **K32** relate the structures of a sperm and an ovum to their functions in reproduction **S6** identify the structures of a sperm and an ovum in electron micrographs or biological drawings **K33** describe the cyclic changes of the uterine lining in the menstrual cycle and the process of ovulation **K34** state the function of hormones (FSH, LH, progesterone and oestrogen) on the female reproductive system[15] **K35** describe the transfer of semen during sexual intercourse and the process of fertilisation **K36** recognise the importance of implantation and the formation of the placenta in the development of embryo and foetus **K37** state the functions of the amnion and the amniotic fluid	• Examine electron micrographs or video clips of sperms and an ovum. • Watch video clips about the process of fertilisation. • Examine photos or video clips taken by ultrasound showing different stages of foetal development. • Discuss how alcohol consumption, smoking or improper diet affect the development of a foetus. • Search for information about the benefits of breast feeding. • Conduct a project work on family planning including genetic counselling and prenatal testing. • Read articles about the discovery of cell-free fetal DNA in maternal blood and the development of noninvasive prenatal testing.

[15] Interaction of hormones in controlling the menstrual cycle is not the learning and assessment focus.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K38 relate the structures of the placenta and the umbilical cord to their functions in the exchange of materials between a mother and her foetus **K39** recognise the change in dietary requirements of a pregnant woman during her pregnancy **K40** recognise the process of labour **K41** recognise the significance of parental care and the advantages of breast-feeding **K42** recognise the importance of prenatal testing using Down Syndome as an example **K43** describe the biological basis of various birth control methods (rhythm method, contraceptive pills, condoms, intra-uterine contraceptive device (IUCD), spermicides and surgical methods) and their effectiveness **K44** recognise the causes and treatment (*in vitro* fertilisation (IVF)) of infertility	• Search for information about various birth control methods (including some wrong methods commonly shared among the teenagers) and their effectiveness. • Search for information on the human reproductive technology. • Read articles about Robert Edwards on the development of *in vitro* fertility (IVF) therapy.

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the impact of the application of biology to human activities (e.g. birth control, treatment of infertility)
- the scientific and technological advancement (e.g. computing technology and image analysing technology) have enhanced our understanding of complex life processes
- the application of biological knowledge (e.g. birth control, application of artificial vegetative propagation and artificial pollination in horticulture, agriculture and conservation) in society and its social, ethical, economic and environmental implications.

Nature of Science

- the biological knowledge and theories are developed through observations, hypotheses, experimentations and analyses (e.g. the ways of seed and fruit dispersal)
- the limitations of scientific activity (e.g. investigations on various physiological processes in plants and humans)

VIII. Genetics (19 hours)

Overview

In this Unit, students will develop an understanding of various genetics concepts from different perspectives. At the cellular level, students will study genes as discrete units of hereditary information encoded in the DNA molecules within the nucleus of every cell. Based on the work of Mendel's pea experiments, students will learn about the inheritance in humans and other organisms, including codominance, multiple alleles, sex determination and sex-linkage, etc. At the molecular level, students will study the components of DNA and RNA, and the central dogma of molecular biology which describes the flow of genetic information from DNA to RNA to protein, through transcription and translation. Lastly, students will learn that mutations in the DNA sequence of a gene or chromosome may lead to changes in phenotypes.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Organisation of genetic materials in cells	**K1** describe the structural and functional relationships of chromosomes, genes and DNA **K2** recognise that the number of chromosomes and number of genes vary in different species **K3** recognise that different genes are at different loci on the chromosomes **K4** distinguish between linked genes and unlinked genes with reference to their locations on chromosomes	• Watch an animation about the structural relationships of chromosomes, genes and DNA. • Construct a model of a chromosome showing the relationships of chromosomes, genes and DNA. • Search for information about the number of chromosomes and number of genes in

Topics Students should learn	Learning outcomes K Knowledge and understanding S Skills and processes/practices Students should be able to	Suggested learning and teaching activities
	K5 state that an allele is one of two or more versions of a gene	different organisms (e.g. fruit flies, rice, mice, humans).
Inheritance	K6 distinguish between phenotypes and genotypes K7 recognise that Mendel's laws of inheritance were based on breeding experiments with pea plants K8 state that the dominant allele masks the effect of the recessive allele in a heterozygous condition K9 relate the segregation of alleles and the independent assortment of alleles to the chromosome behaviour in meiosis K10 explain the inheritance of codominant alleles and multiple alleles using the inheritance of ABO blood group in humans as an example K11 explain the determination of sex and inheritance of sex-linked[16] traits in humans S1 construct and interpret genetic diagrams, including Punnett squares, to explain and predict the outcomes of monohybrid crosses that involve dominance, codominance and sex linkage S2 analyse pedigree to study the inheritance of traits	• Read articles about the contribution of Gregor Mendel to the study of genetics. • Use computer simulations or other materials (e.g genetic corn) to study patterns of inheritance. • Conduct a project on the inheritance of some human traits in a family (e.g. tongue rolling, ear lobes and haemophilia) and construct a pedigree for the inheritance of the traits. • Observe and analyse variations in humans (e.g. height and tongue rolling).

[16] Limited to X-linked recessive traits

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K12 state that the phenotypes of an organism are determined by genetic factors and environmental factors **K13** recognise that some phenotypes are affected by multiple genes **K14** distinguish between continuous variation and discontinuous variation in phenotypes	
Genes and genome	**K15** recognise that different genes are segments of DNA with different nucleotide sequences **K16** state the components of the nucleotides in DNA and RNA **K17** state that nucleic acids (DNA and RNA) are polymers of nucleotides **K18** describe the structure of a DNA molecule[17] as a double helix made of two antiparallel strands of polynucleotides linked by hydrogen bonds between complementary base pairs **K19** state that there are coding regions and non-coding regions in a DNA **K20** state that a genome is the complete set of genetic materials of an organism **K21** recognise that the genome sizes are different in different species	• Construct models of DNA. • Read about the works of some scientists (e.g. James Watson and Francis Crick) in the discovery of DNA. • Search for information about the genome sizes in different species (e.g. bacteria, fruit flies, rice, mice, humans).

[17] Refer to Appendix 3 (TBC)

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
DNA replication, transcription, and translation	**K22** recognise that the replication of DNA takes place during the interphase by complementary base pairing **K23** state the role of DNA polymerase in the replication of DNA **K24** recognise that DNA synthesis and RNA synthesis proceed in a specific direction from 5' to 3' **K25** state the locations in the cell where DNA replication, transcription and translation respectively occur **K26** state that protein synthesis involves transcription and translation **K27** distinguish between the template strand and the coding strand in a DNA **K28** state that transcription involves the synthesis of messenger RNA (mRNA) using the DNA sequence of a gene as a template **K29** state that translation involves the synthesis of protein using mRNA sequence as a template **K30** state the roles of RNA polymerase, transfer RNA (tRNA) and ribosome in protein synthesis **K31** state the features of genetic codes in protein synthesis **S3** work out the nucleotide sequence of an mRNA from a DNA sequence	• Watch animations illustrating the process of DNA replication. • Watch animations illustrating the process of transcription and translation. • Use computer simulation to study the process of protein synthesis.

Topics Students should learn	Learning outcomes K Knowledge and understanding S Skills and processes/practices Students should be able to	Suggested learning and teaching activities
	S4 work out the amino acid sequence of a polypeptide from the nucleotide sequence of an mRNA using the codon table	
Mutation	K32 recognise that there are chromosome mutation and gene mutation K33 state that mutation can be spontaneous mutation and induced mutation K34 recognise that radiation, chemicals and viruses may induce mutation K35 state that mutations in gametes are inheritable K36 explain the possible effects of gene mutations on protein synthesis K37 explain that gene mutations may have no effect on the phenotype S5 interpret karyograms in humans	• Examine photomicrographs showing karyotypes of chromosome mutation (e.g. Down syndrome). • Search for information about some diseases caused by gene mutation (e.g. sickle-cell anaemia). • Search for information about the sources of some mutagenic agents and their effects on human health.

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the application of knowledge of inheritance and molecular genetics in society and its social, ethical and economic implications.

Nature of Science

- the contributions of various people (e.g. Gregor Mendel) to the understanding of genetics
- Mendel's deduction of Laws of Inheritance illustrates how scientists work – through observations and making hypotheses, verifying them through careful experimental design and analysis of experimental results, and drawing valid conclusions.
- the dynamic nature of biological knowledge (e.g. from Mendel's inheritance to molecular genetics)
- scientific theories usually evolve with new evidence (e.g. scientists came to refute protein as the genetic material when emerging experimental evidence pointed to DNA)
- the importance of imagination in theorising, as scientific theories do not emerge automatically from data and its analysis alone (e.g. Mendel suggesting the Laws of Inheritance well before the existence of genes was realised; Watson and Crick proposing the anti-parallel double helical structure of DNA)
- the work of scientists in one field may contribute to the development of ideas in another (e.g. Watson and Crick drew upon evidence worked out by scientists in different fields to build their hypothesis of the double helical structure of DNA)
- the contributions of various people (e.g. James Watson, and Francis Crick) to the understanding of genetics
- the advancement of the study of genetics from traditional breeding experiments to molecular experimentation and analysis

IX. Evolution and Biodiversity (19 hours)

Overview

In this Unit, students will explore the evidence from various scientific disciplines that support evolution and study the theory of evolution through the mechanisms of natural selection. Besides, students will learn about the process of speciation, by which new species arise. Based on the rich biodiversity on the Earth, students will then learn about the phylogenetic approach for classifying living organisms with evidence gathered from molecular genetics. This will enable students to appreciate the phenomena of natural selection.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Evidence of evolution	**K1** recognise that evolution theory stated all living things are descent from a common ancestor **K2** recognise that fossil records, comparative anatomy, nucleotide sequence and amino acid sequence are used as evidence of evolution **S1** analyse various evidence to deduce the phylogenetic relationships of organisms **S2** interpret a phylogenetic tree	• Read articles about the studies of some biologists (e.g. Jean- Baptiste Lamarck, Charles Darwin and Alfred Wallace) on evolution. • Read articles about the researches on palaeontology conducted by the Chinese Academy of Sciences.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Natural selection	**K3** recognise that mutations are sources of genetic variations **K4** describe the process of natural selection as a mechanism of evolution **K5** recognise that natural selection would lead to a change in the proportion of different alleles of genes in a population over time **S3** identify the selection pressure and favourable traits of individuals in a population and predict the possible changes in the proportion of alleles of a population from the data given	• Read articles about some examples of natural selection (e.g. peppered moth and pesticide-resistant insects). • Use computer simulations or other methods to model natural selection. • Illustrate the development of strains of antibiotic resistant bacteria as an example of natural selection • Search information about the natural selection of the anole lizards.
Speciation	**K6** recognise that new species are formed from pre-existing species over time **K7** outline the process of speciation as a result of isolation[18] and natural selection	• Read articles about some examples of speciation (e.g. the Galapagos finches). • Watch video clips or animations on how the population of anole lizards split and multiply into many different species with distinct traits.

[18] Specific types of isolation are not the focus of learning and assessment.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Biodiversity and classification of organisms	**K8** recognise the need for the classification of organisms **K9** state that a species is a group of organisms that share common characteristics and are capable of breeding to produce fertile offspring **K10** recognise the use of the binomial system of naming species **K11** recognise that classification can be based on morphology, anatomy, molecular biology (e.g. the amino acids sequence of proteins and the nucleotide sequences of genes) **K12** recognise that classification systems are subject to change when new evidence appears **K13** state that organisms are classified into three domains[19] (Bacteria, Archaea and Eukarya) based on the comparison of ribosomal RNA sequences **K14** state that organisms of the three domains are classified into six kingdoms (Eubacteria, Archaebacteria, Protista, Fungi, Plantae and Animalia) **S4** classify organisms into six kingdoms **S5** construct and use dichotomous keys to identify organisms **K15** state the importance of biodiversity	• Search for information about the binomial naming of some organisms. • Read articles about the work of Carl Linnaeus and his system of naming organisms. • Search for information about the limitations of some classification systems. • Examine a phylogenetic tree based on the comparison of ribosomal RNA sequences. • Watch video clips about the diversity of organisms under the six kingdoms. • Watch video clips about the biodiversity in Hong Kong. • Visit the Hong Kong Biodiversity Museum. • Search for information about the biodiversity in Hong Kong from some reliable websites (e.g. Hong Kong Biodiversity Information Hub).

[19] Proposed by Carl Woese in 1990

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	S6 evaluate the level of biodiversity of a habitat based on the species richness and the relative abundance of each species	• Study the biodiversity of habitats based on the data collected from field studies or some second-hand data from some biodiversity surveys.

*(*Note: The underlined text represents the content of the extension part)*

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the theory of natural selection help understand that misuse of antibiotics sped up the development of resistant bacteria and superbug
- the relation of the theory of natural selection to selective breeding and genetic modification of crops and livestock

Nature of Science

- scientific knowledge is durable and tentative. (e.g. the development of classification systems, the explanation for evolution)
- scientific knowledge is supported by evidence. (e.g. fossil records, comparative anatomy, nucleotide sequence and amino acid sequence are used as evidence of evolution)
- scientific knowledge is influenced by societies (e.g. various views on the origin of life and evolution)

X. Biotechnology (22 hours)

Overview

In this Unit, students can study the general principles of biotechnology and its wide range of applications. This will enable them to recognise biotechnology as a rapidly expanding branch of Biology. Besides learning about the applications of traditional biotechnology in food production and selective breeding, students will also learn about the different techniques in molecular biology, including polymerase chain reaction, DNA gel electrophoresis, DNA fingerprinting, and DNA sequencing. They will then learn about the applications of recombinant DNA technology in genetic engineering, such as genetic modification of organisms and cloning. They will also become familiar with the applications of biotechnology in the areas of medicine and agriculture, and be aware of the ethical, legal, social, economic and environmental implications of biotechnology. Issues related to the research and developments in biotechnology, as well as its contribution to the advancement of biology will also be discussed.

Topics Students should learn	Learning outcomes K Knowledge and understanding S Skills and processes/practices Students should be able to	Suggested learning and teaching activities
Traditional biotechnology	K1 state that microorganisms are used in fermentation for food production K2 describe the different phases (lag phase, log phase, stationary phase and death phase) of microbial growth using bacterial growth as an example K3 state the growth requirements (temperature, pH, nutrients, oxygen and water availability) of microorganisms K4 recognise that bioreactors are used in industry for the mass cultivation of microorganisms K5 recognise the importance of sterilisation to industrial fermentation process S1 use aseptic techniques and follow the safety procedures to culture microorganisms[20] S2 use colony count and optical density method to measure the growth of microorganisms K6 recognise that modification of domesticated plants and animals can be made through selective breeding	• Search for information on the food that are produced by fermentation. • Perform practical work to culture yeast and non-pathogenic bacteria on agar plate and in liquid culture using aseptic techniques. • Perform serial dilutions and spread plate to estimate the amount of bacteria in probiotic drinks. • Perform practical work on the application of the fermentation process (e.g. bread-making, beer-brewing and wine-making). • Design and perform investigations to study the optimal conditions necessary for fermentation by yeast in bread-making. • Visit a food production plant involving fermentation process.

[20] Restricted to the culture of non-pathogenic microorganisms.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Techniques in molecular biology	**K7** recognise that various techniques in molecular biology are used to manipulate the biomolecules of cells including DNA, RNA and proteins	
• Polymerase chain reaction (PCR)	**K8** outline the principle of PCR **K9** describe the steps (denaturation, annealing and extension) involved in PCR for selective amplification of DNA fragments **K10** state the roles of primers and heat-stable DNA polymerase in PCR **K11** recognise the wide applications of PCR **S3** predict the size of the PCR products	• Read articles about the contributions of scientists (e.g. Kary Mullis) in the invention and development of PCR. • Watch video clips or animations illustrating the principle of PCR. • Search for information on the applications of PCR.
• DNA gel electrophoresis	**K12** outline the principle of DNA gel electrophoresis **S4** perform gel electrophoresis to separate DNA fragments	• Perform practical work to amplify DNA fragments using PCR and to separate DNA fragments using gel electrophoresis.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
• DNA fingerprinting	**K13** recognise the occurrence of DNA polymorphism in terms of VNTRs (variable number tandem repeats), STRs (short tandem repeats) and SNPs (single nucleotide polymorphisms) **K14** recognise that DNA fingerprinting is a technique for determining the identity of humans or other organisms based on DNA polymorphisms **K15** outline the principle of STR analysis **K16** recognise the applications of STR analysis in forensic science and paternity testing **S5** interpret DNA fingerprints	• Read articles about the contributions of scientists (e.g. Alec Jeffreys) in the invention and development of DNA fingerprinting. • Watch animations illustrating the principle of STR analysis. • Perform practical work on STR analysis (e.g. paternity test and forensic test).
• DNA sequencing	**K17** state the applications of DNA sequencing **K18** recognise that genome projects have sequenced the genomes of organisms ranging from microbes, plants to humans **K19** recognise the uses of DNA sequence databases	• Search for information on the Human Genome Project (HGP) and its implications. • Use the BLAST (Basic Local Alignment Search Tool) to check for the similarity of DNA sequence of some common proteins (e.g. insulin) between humans and other species.
Genetic engineering		

Topics Students should learn	Learning outcomes K Knowledge and understanding S Skills and processes/practices Students should be able to	Suggested learning and teaching activities
• Recombinant DNA technology	**K20** state that a recombinant DNA is made by combining DNA fragments from different sources or organisms **K21** describe how desired DNA fragments can be obtained from various sources (extraction from a donor organism, synthesised from the RNA of a donor organism, synthesised chemically with nucleotides) **K22** outline the principle of recombinant DNA technology (restriction digestion, ligation, transformation, multiplication and selection of the transformed cells and expression of the gene to produce the desired product) using the production of insulin as an example **K23** explain why bacteria are commonly used in recombinant DNA technology **K24** explain how bacteria successfully transformed with the genes of interest can be selected using marker genes	• Read articles about the contributions of scientists (e.g. Herbert Boyer and Stanley Cohen) in the invention and development of recombinant DNA technology. • Watch animations illustrating the principle of recombinant DNA technology. • Perform practical work involving recombinant DNA technology.
• Applications of genetic engineering in medicine and agriculture	**K25** recognise the applications of recombinant DNA technology in medicine (disease diagnosis, the production of drugs and vaccines, disease treatment) **K26** outline the major steps of producing genetically modified (GM) plants **K27** recognise the major steps of producing GM animals	• Search for information on the recombinant drugs and vaccines available. • Search for information on the diagnostic test kits for infectious diseases using recombinant DNA technology.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K28 recognise the use of GM plants and animals in scientific research, food industry and agriculture **K29** recognise the potential uses of gene editing	• Read articles about the development of gene therapy. • Watch video clips about the production of GMOs (e.g. the GM papaya, GM salmon). • Read articles about the first GM plant and the first commercially available GM crop in the world. • Search for information on some GM animals approved for human consumption. • Read articles about the contributions of scientists (Emmanuelle Charpentier and Jennifer Doudna) in the invention of the technology "CRISPR-Cas9 genetic scissors". • Read articles about the approved CRISPR therapy for blood disorders (e.g. sickle cell disease). • Read articles about the potential use of transplantation of gene-edited animal organs in humans.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
		• Search for information on the gene-edited crops available in the market.
Cloning	**K30** outline the major steps of somatic cell nuclear transfer in the cloning of mammals using Dolly the sheep as an example **K31** outline the major steps of tissue culture in plant cloning	• Watch animations illustrating the principle of somatic cell nuclear transfer in cloning. • Perform practical work on cauliflower cloning.
Bioethics	**K32** recognise the ethical, legal, social, economic and environmental issues of biotechnology in agriculture and medicine	• Search for information on some facts and myths about GM crops. • Compare the regulations and rules about the cultivation and sale of GM crops or animals in China and other countries. • Search for information about the surveys conducted by Agricultural, Fisheries and Conservation Department for the presence of GMOs in local markets and farms in Hong Kong. • Compare the gene therapy approved for use in China and other countries. • Search for information on the safety and efficacy of gene therapy.

Topics Students should learn	Learning outcomes **K** Knowledge and understanding **S** Skills and processes/practices Students should be able to	Suggested learning and teaching activities
		• Debate on the issues related to animal and plant cloning. • Discuss the environmental issues related to the application of biotechnology.

*(*Note: The underlined text represents the content of the extension part)*

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the needs of the society needs have led to technological advances (e.g. recombinant DNA technology and DNA fingerprinting; the production of genetically modified crops to solve food shortage problem)
- scientific and technological advancement (e.g. DNA sequencing) have enhanced our understanding of the genomes of humans and other organisms.
- the application of biological knowledge (e.g. fermentation in food production, the use of bacteria in biotechnology) and their social, economic and environmental implications
- scientific knowledge may lead to the development of new technology (e.g. understanding of the characteristics of heat stable enzymes leading to the invention of PCR technology)

- science has been influenced by societies (e.g. debates on human cloning)
- the social impact of the rapid advances in DNA technology may affect one's personal decisions

Nature of Science

- the contributions of various people in biotechnology (e.g. Herbert Boyer and Stanley Cohen – development of recombinant DNA technology, Kary Mullis – invention of PCR technique, and Alec Jefferys – development of DNA fingerprinting, Frederick Sanger – development of the first generation DNA sequencing.)
- the joint effort of scientists in the development of biotechnology (e.g. the joint effort and peer review of scientists in the US, the UK, France, Germany, Japan and China have contributed to the rapid achievements in the Human Genome Project)
- the limitations of the application of DNA fingerprinting in forensic science
- science has its limitations and cannot always provide clear-cut answers in certain areas, such as the ethical issues resulted from the applications of various DNA technologies

XI. Health and Diseases (20 hours)

Overview

In this Unit, students will develop an understanding of what constitutes health. This Unit is designed to help students develop positive attitudes towards health and be aware of both individual and public responsibility for maintaining a healthy community so that they can make informed decisions on the choice of lifestyles, disease prevention measures, and disease treatments. They will learn about the risk factors for the development of non-infectious diseases in general and then have a more focused study on cancer and the risk factors of various types of cancer. They will then learn about the chain of infection related to infectious diseases, and the biological principles of their prevention and control. Students will develop a deeper understanding of infectious diseases through two case studies with one bacterial disease and one viral disease. Besides, students will learn about the physiological defence mechanisms employed by the human body to combat diseases and the principle of vaccination.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Health	**K1** recognise the meaning of health **K2** recognise some factors that affect health **K3** recognise the influence of lifestyle on health	• Search for information on some health tips (e.g. healthy eating, physical activity, visual and hearing health, bones and spinal health, and healthy use of internet and electronic screen products) for adolescents. • Conduct a project on the harmful effects of alcohol consumption.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
		• Design a poster on anti-drugs promotion.
Non-infectious diseases	**K4** recognise that the development of non-infectious diseases depends on multiple risk factors	• Search for information on some common non-infectious diseases (cardiovascular diseases, cancer, hypertension and diabetes) and the risk factors related to these non-infectious diseases.
• Cancer	**K5** state that uncontrolled growth of cells may lead to the formation of tumours **K6** distinguish between benign tumours and malignant tumours **K7** recognise that mutations to genes controlling the cell cycles or are responsible for DNA repair may lead to uncontrolled growth of cells **K8** recognise that cancer can be caused by gene mutations building up over times **K9** outline the risk factors (genetics, aging, infection, lifestyles and exposure to carcinogens) of cancer **S1** interpret data to identify the risk factors of a specific cancer **K10** state the preventive measures (healthy lifestyle, reduce exposure to carcinogens, vaccination, undergo cancer screening) for cancer	• Examine photomicrographs or prepared slides of malignant tissues. • Perform practical work to simulate DNA microarray analysis to differentiate the gene expression patterns in normal and in cancerous cells. • Conduct a project on the incidence of liver cancer and lung cancer in relation to lifestyles. • Design a poster or leaflet to advise how to reduce the risks of developing a type of cancer.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K11 recognise the benefits of cancer screening in the early detection of cancer	• Search for information about some genetic testing (e.g. BRCA gene mutations for breast and ovarian cancers). • Search for information on the common screening programmes for cancers (e.g. cervical cancer and colorectal cancer) in Hong Kong.
Infectious diseases	**K12** state some common types of pathogens (viruses, bacteria, fungi and protists) **K13** outline the chain of infection (infective agent, source of infection, mode of transmission, host) **K14** suggest some ways of infection control to break the chain of infection **K15** recognise infectious diseases caused by various types of pathogen can be treated by specific drugs	• Examine photomicrographs or prepared slides of some pathogens (e.g. viruses, bacteria, fungi and protists). • Conduct a project on infectious diseases (e.g. hepatitis B, AIDS, dengue fever, tuberculosis, athlete's foot or malaria) with reference to their ways of transmission, symptoms, treatments and ways of infection control. • Read stories about the contributions of scientists (e.g. Alexander Fleming, Ernst Chain and Howard Florey) to the discovery and development of penicillin.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Body defence mechanisms • Non-specific defence mechanisms	**K16** identify the natural barriers against pathogens **K17** state the significance of blood clotting, inflammatory response and phagocytosis	• Examine prepared slides, photomicrographs or a model of mammalian skin to identify features that are related to body defence. • Examine prepared slides or photomicrographs of phagocytes. • Watch video clips or animations on phagocytosis, blood clotting and inflammatory responses.
• Specific defence mechanism[21]	**K18** outline the events (recognition of foreign antigens, proliferation of effector B cells and effector T cells, production of antibodies by effector B cells, destruction of infected body cells by effector T cells, and production of memory cells) that occur during a primary immune response **K19** describe the actions of antibodies against pathogens and the toxins released by the pathogens	• Examine prepared slides or photomicrographs of lymphocytes. • Watch animations on primary immune response. • Watch animations on secondary immune response.

[21] Details about the roles of macrophage, antigen-presenting cells and helper T-cells are not the learning and assessment focuses.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K20 describe the role of memory cells in the secondary immune response **K21** compare primary immune response and secondary immune response **K22** distinguish between active immunity and passive immunity **K23** distinguish between natural immunity and artificial immunity	
Prevention of infectious diseases	**K24** outline the principle of vaccination **K25** state the types of vaccines (inactivated vaccines, messenger RNA (mRNA) vaccines, recombinant vaccines) **K26** recognise the importance of immunisation programme in the control of infectious diseases **K27** recognise the personal responsibility in preventing disease transmission and the importance of community health **S2** interpret the graph showing changes in the overall immune response over time after vaccination	• Read stories about the contributions of scientists (e.g. Edward Jenner, Louis Pasteur and Jonas Salk) to the development of vaccination. • Watch animations on how immunisation programmes help control infectious diseases through herd immunity. • Search for information on the relation of immunisation programmes to the control of infectious diseases (e.g. polio and measles), and the outbreaks of infectious diseases in Hong Kong.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
		• Study a personal immunisation record to find out the diseases that are covered by the local immunisation programme.
A case study of bacterial diseases: tuberculosis	**K28** recognise the pathogen causing tuberculosis and its mode of transmission **K29** state the actions (inhibition of cell wall synthesis, inhibition of protein synthesis) of antibiotics using antibiotics against tuberculosis as an example **S3** interpret results of antibiotic susceptibility test using the disc diffusion method **K30** outline how the misuse of antimicrobials leads to the development of antimicrobial resistance	• Design and perform an investigation to study the effect of antibiotics on bacterial growth. • Watch video clips or animations illustrating the development of antimicrobial resistance.
A case study of viral diseases: influenza	**K31** recognise the pathogen causing influenza and its mode of transmission **K32** outline how an influenza virus reproduces by infecting a living cell (attachment to a host cell, entry of genetic materials, hijack of the host cell machinery for virus replication, release of viruses) **K33** recognise that RNA viruses are prone to mutation leading to new variants of influenza viruses	• Watch animations about the structure of an influenza virus. • Watch video clips or animations about the events of a viral life cycle. • Watch animations about the principle of RT-PCR (reverse transcription polymerase chain reaction) test.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K34 recognise that RT-PCR (reverse transcription polymerase chain reaction) test and antigen test can be used for the diagnosis of influenza **K35** state that vaccination is a way to prevent influenza **K36** explain why the influenza vaccine requires frequent reformulation	• Watch animations about the principle of an antigen test. • Search for information on the viral strains in the current seasonal influenza vaccine composition.

*(*Note: The underlined text represents the content in the extension part)*

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the application of biological knowledge in maintaining a healthy community and its social, ethical, economic and environmental implications;
- the needs of the society have led to technological advances (e.g. treatment and prevention of diseases);
- modern technological advances and scientific discoveries contribute to the detection, diagnosis, treatment, prevention and monitoring of diseases (e.g. RT-PCR test, antigen test, and mRNA vaccines); and
- personal responsibility in preventing disease transmission and the importance of herd immunity in public health.

Nature of Science

- the dynamic nature of biological knowledge related to body defence mechanism and diseases, and understand that science is durable and tentative;
- the contributions of various people in advancing the application of biology (e.g. the development of vaccines and the discovery of antibiotics);
- biological knowledge and theories related to the prevention and control of diseases are developed through observations, hypotheses, experimentations and analyses;
- the different approaches adopted in the study of diseases are scientific inquiries focusing on different aspects of a disease; and
- the nature and limitations of scientific activity (e.g. the causes and transmission of some diseases are not yet known, no vaccines can provide full (100 %) protection.

XII Conservation and Sustainable Development (20 hours)

Overview

In this Unit, students will build on their prior knowledge of basic ecological principles to understand conservation and sustainable development. For the topic of conservation, students will learn about the principles and measures to protect, preserve, and restore the natural environment and its resources. This includes some measures to safeguard ecosystems, habitats, and species from exploitation and destruction. Students will study the conservation measures in the local context using the Mai Po and the Inner Deep Bay wetlands as examples. For the topic of sustainable development, students will learn about the principles and measures for mitigating environmental challenges such as climate change and eutrophication resulting from increasing human activities. Students will learn about the need to safeguard the food security and the principles of sustainable agriculture. In addition, a case study of growing soybeans in marginal lands is an example to illustrate how to maintain the food supply for the growing human population. Overall, students should be aware of the responsibility of individuals, communities and governments to manage our resources and activities in a way to ensure there will be a more sustainable and resilient future for our next generations.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
Conservation	**K1** state the types of ecosystem services (provisioning, regulating, cultural and supporting) **K2** recognise the needs for conservation	• Visit some afforestation areas and Fung Shui woods in Hong Kong.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K3 recognise the environmental, ethical, social and economic issues related to conservation	• Participate in the school education programmes offered by the Agriculture, Fisheries and Conservation Department. • Participate in some conservation activities (e.g. beach cleanup, Mikania removal and tree plantation).
• Conservation of species and genetic diversity	**K4** outline the causes (habitat loss, invasive species, over-exploitation, pollution and climate change) of biodiversity loss **K5** recognise that the extinction risk of species are recorded in the Red List of Threatened Species maintained by the International Union for Conservation of Nature (IUCN) **K6** recognise the importance of protection of endangered species **K7** recognise some endangered species in in our country and Hong Kong **K8** state the significance of conserving species diversity and genetic diversity **K9** explain the importance of keystone species and dominant species in maintaining the ecosystem structure	• Search for information about the threatened species in the IUCN Red List of Threatened Species. • Search for information about some endangered species in our country (e.g. South China tiger, black crested gibbon, white-shouldered ibis, Chinese alligator, Chinese giant salamander, and Chinese sturgeon). • Search for information about some endangered species in Hong Kong (e.g. Chinese white dolphin, black-faced spoonbill, Romer's tree frog, Grantham's camellia).

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K10 state the principles (enhancing population growth, reducing population loss) of measures for species conservation **S1** evaluate the effectiveness of different conservation measures through data analysis	• Visit the Endangered Species Resource Centre. • Visit the breeding research base for some endangered species in our country. • Discuss the conservation of an endangered species regarding population size, reasons for concern, measures introduced and international cooperation required. • Search for information on some measures of conservation of species diversity and genetic diversity (e.g. legislation, monitoring species population through biodiversity surveys, assisted reproduction, seed banks, cloning of endangered species, control of invasive alien species, control of genetically modified organisms and prevention of inbreeding).
• Conservation of habitats	**K11** describe the importance of ecological restoration in terms of habitat complexity and essential ecosystem services	• Search for information on some measures of habitat conservation or restoration (e.g. establishment of ecological corridor at the

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K12 describe the ecological significance (restoration of ecosystem services and biodiversity) of the afforestation projects in the country parks in Hong Kong **K13** recognise the types of conservation areas in Hong Kong (country parks and special areas, marine parks and marine reserve, the Ramsar site and Sites of Special Scientific Interests (SSSIs)) **S2** evaluate the effectiveness of different habitat conservation or restoration measures through data analysis	Ting Kau end of Tai Lam Tunnel, establishment of fish ladder in the Ho Chung River improvement works and River Improvement Works in Upper Lam Tsuen River, and the Hong Kong Artificial Reef Project). • Search for information on the afforestation projects in country parks to understand why native trees rather than exotic trees are planted. • Visit a conservation area in Hong Kong (e.g. Sites of Special Scientific Interests (SSSIs), country parks, marine parks and marine reserve, and the Ramsar sites).
A local case of conservation : Mai Po and the Inner Deep Bay wetlands	**K14** state the importance of wetland and the ecosystem services provided by wetland **K15** recognise the biodiversity (species diversity and ecological diversity) at the Mai Po and the Inner Deep Bay wetlands **K16** identify the threats to the biodiversity at the Mai Po and the Inner Deep Bay wetlands	• Participate in an education programme or an eco-tour at the Mai Po Nature Reserve to learn about the conservation measures (e.g. establishment of conservation areas, ecological baseline monitoring programme, land use and water quality control,

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K17 recognise the principles of some conservation measures in Mai Po Nature Reserve and the Hong Kong Wetland Park	conservation projects about fishponds) at the site. • Visit the Hong Kong Wetland Park to learn about the conservation measures in the park (e.g. vegetation management, control of water level and quality, artificial nests for wildlife, control of alien species, planting of habitat enrichment, biodiversity surveys).
Sustainable development	**K18** recognise the importance of environmental sustainability **K19** recognise that some global and regional environmental issues are resulted from urban development	
• Climate change	**K20** recognise the importance of greenhouse effect in sustaining lives on Earth **S3** interpret data showing the changes in the global atmospheric concentrations of greenhouse gases (carbon dioxide and methane), global temperature and human activities over time **K21** describe the role of greenhouse gases in causing global warming	• Watch video clips about climate change to understand its causes and effects. • Search for information on some carbon sinks and carbon sources. • Discuss on how some practices (e.g. protect and restore ecosystems, sustainable agricultural practices, afforestation, reduction of food waste and adopting plant-

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K22 state the consequences of climate change on the ecosystem **K23** state the principle (balance the carbon sinks and carbon sources) for combating climate change	based diet) could help combat climate change. • Visit the Organic Resources Recovery Centres (e.g. O · PARK1 and O · PARK2). • Search for information on the policy of the Hong Kong government in combating climate change (e.g. the Hong Kong's Climate Action Plan 2050) to learn about how the government and the citizens work together to combat climate change and achieve carbon neutrality.
• Eutrophication and its control	**K24** describe the causes and effects of eutrophication **S4** interpret and explain data about the changes in the abiotic factors (dissolved oxygen level, phosphate, nitrate and ammonium levels) and the biotic communities along a polluted river **K25** state the measures (treatment of sewage before discharge, substitution of nitrate and phosphate fertilisers with compost) for preventing eutrophication **K26** describe the biological principles of sewage treatment	• Watch some video clips or read some news articles on the problem of eutrophication. • Design and perform an investigation to study the effects of different nutrient concentrations on algal growth. • Conduct a field study to investigate the water quality along a freshwater stream. • Search for information on some new sewage treatment technologies (e.g.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
	K27 state that renewable energy and fertiliser can be obtained from microbial anaerobic digestion of sludge	membrane bioreactors, moving bed biofilm reactors). • Visit a sewage treatment plant. • Visit T · Park to learn about the waste-to-energy process from the treatment of sludge.
• Food security and sustainable agriculture	**K28** recognise the need to ensure the availability of safe and nutritious food for the world population growth **K29** recognise the loss of agricultural land due to urbanisation **K30** recognise the potential challenges (climate change, malpractices in fisheries and agriculture, pollution) on food security **K31** recognise the importance of sustainable agriculture **K32** explain the biological principles of some agricultural practices (intercropping and crop rotation, mixed farming, biological control of pests) for sustainable food production **K33** recognise the biotic and abiotic stress affecting plant growth in the natural environment **S5** interpret data and graphs showing the effects of different factors on crop yield	• Search for information on the world population growth and the world agricultural output. • Search for information on the impacts of climate change, malpractices in fisheries and agriculture, and pollution on food production. • Visit a local organic farm to learn about the principles of sustainable agricultural practices. • Search for information on the mulberry-dyke and fish-pond system in Huzhou, Zhejiang to learn about the principles of sustainable agro-ecological system.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
		• Visit a local agriculture company (e.g. an indoor farming company or a vertical farming company) to learn about modern agricultural technology).
A case study: Growing soybean in the marginal lands	**K34** recognise the nutritional values and uses of soybean **K35** explain why soybean plant is usually used in crop rotation and intercropping **K36** recognise the diversity of wild soybeans that are adapted to habitats with different biotic and abiotic stresses **K37** recognise that desired traits of soybean can be selected by hybrid breeding and marker-assisted breeding	• Perform practical work to study the effects of light on the morphology and chlorophyll production of germinating soybean seedlings. • Cultivate soybean plants from the seeds to observe the growth of the plants at different stages. • Perform practical work to observe the growth of nodules and soybean plants after inoculating *Rhizobia* to the soybean seedlings cultivated in hydroponic system. • Watch video clips about how strains of soybean that are salt-tolerant and drought-tolerant are developed by a local scientist.

Topics **Students should learn**	**Learning outcomes** **K** Knowledge and understanding **S** Skills and processes/practices **Students should be able to**	**Suggested learning and teaching activities**
		• Perform practical work to cross breed two strains of soybean plants with the desired traits. • Perform practical work to check whether the cross-bred soybean plants carry the desired traits using DNA markers.

*(*Note: The underlined text represents the content of the non-foundational part)*

The following curriculum emphases could be introduced through the learning and teaching of relevant topics in this Unit:

Science and Technology for Society and Environment

- the application of ecological knowledge in society and its social, ethical, economic and environmental implications;
- scientific and technological advancement have influenced our lives, society and the environment (e.g. climate change, biodiversity loss due to human activities);
- develop sensitivity and responsibility in striking a balance between the needs of humans and a sustainable environment;
- biological knowledge is used in conserving species and habitats;
- biological knowledge is used in technological application for management of the environment (e.g. sewage treatment); and

- biological knowledge is used in agricultural practices for sustainable food production.

Nature of Science

- the dynamic nature of biological knowledge in ecology and understand that science is a human endeavour;
- biological knowledge and theories are developed through observations, hypotheses, experimentations and analyses (e.g. study of the impact of climate change); and
- understand the nature and limitations of scientific activity.

XIII. Scientific investigations

- Students are expected to master the major skills, processes, and practices for conducting scientific investigations. It is essential to provide sufficient learning experiences for students to carry out scientific investigations throughout the three years of study.
- In order to facilitate the incorporation of scientific investigation into the learning and teaching of biology, time for conducting simple investigations and practical work has already been included in the suggested lesson time for each Unit.
- In addition, there are **20 hours allocated for the conduction of scientific investigations** involving designing experiments and report writing to provide students with opportunities to develop the full range of scientific inquiry skills and appreciate the nature of science.

	Learning outcomes **Students should be able to**
Defining the investigation	• Propose question(s) for an investigation • Formulate the hypothesis for testing (if applicable) • Make relevant prediction(s) of results based on biological principles and/or concepts • Identify the appropriate scientific methods to answer the investigation question(s)
Designing the experiment	• Identify and justify the choice of independent, dependent and control variables • Design a valid experiment or procedure according to the purpose of the investigation • Consider the measurement techniques, the range and number of measurements required • Plan for (an) appropriate control set-up(s) (if applicable) • Consider the proper way of sampling (if applicable) • Identify and take the necessary precautions to minimise any potential risks • Identify significant assumptions of the experimental design
Conducting the practical work	• Carry out the practical work properly • Manipulate apparatus and use instruments properly

	Learning outcomes **Students should be able to**
	• Use proper techniques for carrying out the practical work, e.g. serial dilution or proportional dilution for preparing solutions of different concentrations (if applicable) • Collect qualitative and quantitative data appropriately • Address relevant safety concerns for oneself, others, and the environment during the investigation
Presenting and processing data	• Record the qualitative (categorical or ordered) data in tables • Record the quantitative data appropriately according to the resolution of the equipment, with the most appropriate units in table(s) • Process the raw data with appropriate calculations (e.g. means, percentage gain or loss, rates of change) • Present the processed data with suitable number of significant figures • Sketch or draw suitable graphs, plotting the independent variable on the x-axis and the dependent variable on the y-axis, using appropriate scale • Recognise that the choice between connecting data points with straight line segments or using a best-fit line (straight or curved) to represent data on a graph depends on the purpose of the investigation • Calculate the rate of change using the gradient of a straight line on a graph or the gradient of a tangent to a curved line on a graph
Interpreting data and concluding	• Describe and explain trends, patterns and relationships of variables (e.g. direct and inverse proportionality, positive and negative correlations) • Identify any anomalous data in a table or graph; suggest ways for handling the anomalies and propose possible explanations for the anomalous data • Interpret the results of an investigation in relation to its investigation question(s) or hypothesis • Construct evidence-based explanations in relation to the investigation question(s) or hypothesis • Draw a conclusion from the results of the investigation

	Learning outcomes **Students should be able to**
Evaluating	• Assess whether the range of values of the independent variable and the intervals between the values are appropriate • Assess whether the method of measurement is appropriate for the dependent variable • Assess the extent to which selected variables have been effectively controlled • Identify the errors in measurement and sampling (if any), and suggest ways for reducing such errors • Assess the accuracy, precision and reliability of data collected • Suggest the limitation of the experiment • Suggest how the investigation could be improved

Notes on using digital tools and AI in scientific investigations:

Students are expected to:

- Use appropriate digital tools (e.g. data-loggers and sensors, spreadsheets, graphing software and AI), to collect, process and interpret data, search for and organise biological information, and evaluate the reliability and scientific accuracy of digital and AI-generated outputs.
- Value the importance of using digital tools and AI critically and responsibly, recognising both their benefits and limitations in scientific inquiry.
- Appreciate the need to integrate digital technologies and AI with sound scientific reasoning when solving biology-related problems.

Teachers are expected to allocate 20-hour lesson time to provide opportunities for students to design and conduct scientific investigations on individual topics or cross topics of the Biology Curriculum. A suggested arrangement of a scientific investigation is as below:

	Time allocation
1. Develop an investigation plan or designing an experiment under teacher's guidance	~ 80 minutes
2. Conduct the experiment	~ 80 minutes
3. Organise and analyse data, interpret, and discuss the experimental results, drawing an appropriate conclusion	~ 80 minutes
Total:	240 minutes (4 hours)

- Depending on the nature of the scientific investigation and the students' abilities, teachers could make their own judgments on the time allocated for different investigative tasks, and spread the tasks across the 3-year of study.
- These investigation tasks can be arranged in parallel with the learning of a topic or on the completion of a relevant topic or relevant topics.

Chapter 3 Assessment Framework

3.1 Assessment Objectives

The objectives of the public assessment of Biology are to evaluate candidates' ability to:

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

3.2 Assessment Design

3.2.1 Mode of assessment

The public assessment of Biology consists of a public examination component and a school-based assessment component as outlined in the following table:

Component		Weighting	Duration
Public Examination	Paper 1 Conventional Questions	56%	2 hours 15 minutes
	Paper 2 Multiple-choice Questions	24%	1 hour
School-based Assessment (SBA)		20%	——

3.2.2 Public examination

Paper 1 consists of conventional questions, including short questions, structured questions and essay questions, set on both the Core and Extension components of the curriculum. It carries 56% of the subject mark. Candidates are required to answer **all** questions in Paper 1.

Paper 2 consists of multiple-choice questions set on both the Core and Extension components of the curriculum. It carries 24% of the subject mark. Candidates are required to answer **all** questions in Paper 2.

Questions set on the Extension component would **not** exceed 30% of the written paper marks.

3.2.3 School-based assessment (SBA)

School-based assessment (SBA) is compulsory for **all** school candidates. In the SBA of Biology, candidates are required to perform a stipulated amount of practical work, which may include scientific investigations, laboratory work, and fieldwork, etc. In S5 and S6, they will be assessed in two ability areas: practical skills abilities (A) and reporting of investigative work (B). Ability area A carries 8% of the subject mark, while ability area B carries 12% of the mark.

The table below summarises the percentage weighting and the minimum number of assessments required in S5 and S6 for the different areas of the SBA:

		Ability area A (Practical skills abilities)	Ability area B (Reporting of investigative work)
Weighting in subject		8%	12%
Minimum number of assessments	S5	1	1
	S6	1	1

For monitoring and authentication purposes, candidates are required to keep good custody of all their work in SBA until the publication of the HKDSE examination results.

Private candidates need not complete the SBA component. Their subject result will be based entirely on their public examination result.

The detailed requirements, regulations, assessment criteria, guidelines and methods of assessment are provided in the SBA Teachers' Handbook for HKDSE Biology published by the Hong Kong Examinations and Assessment Authority.

Annex 1

A sub-section to be included in Chapter 4: Learning and Teaching of the Biology (S4-6) Curriculum and Assessment Guide

The Use of Digital Educational Tools and Artificial Intelligence for Learning, Teaching and Assessment of Biology

Digital educational tools and artificial intelligence (AI) provide support for learning and teaching and promote pedagogical innovation in Biology. Through the appropriate use of digital tools and AI-assisted strategies, teachers can design interactive learning activities, better understand students' learning progress and needs, and enhance teaching effectiveness through diversified pedagogical approaches.

In Biology learning and teaching, AI technologies, such as generative AI (GenAI), personalised learning platforms and learning analytics tools, can be used to support the design of learning activities and assessment tasks that are more closely aligned with students' learning needs. In particular, AI tools can assist teachers in analysing students' learning performance, identifying misconceptions and learning difficulties, and providing feedback or suggestions for refining learning and teaching materials, thereby supporting students' learning in Biology.

With appropriate teacher guidance and the development of fundamental digital skills, AI-assisted learning tasks can also support effective self-directed learning. These learning experiences can enhance students' learning motivation and self-reflection, while strengthening their knowledge acquisition and conceptual understanding.

Teachers may make appropriate use of AI and digital educational tools, including simulations, animations, three-dimensional visualisation of cellular and molecular structures, and data analysis tools, to help students develop a deeper understanding of abstract biological concepts, particularly those involving sub-cellular structures, molecular interactions and physiological processes. Online learning platforms and AI-assisted tools may also be used to provide students with diversified learning experiences and timely feedback, thereby promoting self-directed learning and enhancing learning effectiveness.

The following are examples of applications of digital educational tools for teachers' reference:

Digital Educational Tools	Pedagogical Use
Computer Simulations	• Enable students to visualise and manipulate abstract or sub-microscopic entities and processes (e.g. enzyme-substrate interactions and enzyme action, photosynthesis and cellular respiration, cell division stages including mitosis and meiosis) in a virtual environment. • Interactive simulation experiments allow students to manipulate variables (such as temperature, pH, light intensity, or substrate concentration) and relate biological concepts to experimental observations. • Help address misconceptions and promote conceptual understanding through inquiry-based exploration.

Online Learning and Assessment Platforms	• Provide online Biology-related lectures, reading activities, interactive learning resources on experiments and data analysis, and online assessments with instant feedback. • Support formative assessment, help teachers identify learning difficulties, and promote self-directed and collaborative learning beyond the classroom.
Data-loggers and Sensors	• Facilitate real-time data collection and instant graphical representation in practical work. • Support scientific inquiry by enabling students to design experiments, observe trends promptly (e.g. in photosynthesis rates, enzyme activity, or heart rate during exercise), and focus on data interpretation, evaluation and discussion rather than manual data plotting.
Mobile Devices	• Enable students to conduct experiments using mobile applications (e.g. measuring plant growth, analysing leaf chlorophyll content, or simulating ecological sampling). • Allow students to capture videos of biological processes (such as seed germination, animal behaviour, or simple dissections) and analyse them qualitatively or quantitatively.
Multimedia Resources (Animations and videos)	• Animations and videos help students visualise abstract concepts and physiological or cellular processes that are otherwise inaccessible (e.g. simple biochemistry pathways in photosynthesis, DNA replication, or nerve impulse transmission). • Stimulate interest, support conceptual understanding, and allow repeated observation of experimental techniques and phenomena.
Artificial Intelligence (AI)	• Support diagnostic and formative assessment by analysing students' responses to identify misconceptions, learning difficulties and topic-specific weaknesses (e.g. in genetics inheritance patterns, ecological relationships, or human physiology regulation). • Provide adaptive learning and practice tasks (e.g. Punnett squares and probability in genetics, interpreting food webs, or understanding homeostatic feedback mechanisms) to support progressive skill and concept development. • Enhance learning through visualisation and modelling of abstract and sub-microscopic concepts (e.g. molecular structures in enzymes, membrane fluidity, phylogenetic trees, or biodiversity patterns). • Assist teachers in designing curriculum-aligned learning and assessment materials tailored to students' needs, thereby creating curriculum space for laboratory work, discussion on socio-scientific issues (e.g. conservation, biotechnology ethics), and deeper conceptual understanding.

The table below helps teachers identify and select appropriate digital educational tools according to specific purposes of learning activities in Biology, illustrating how different tools can be used flexibly and complementarily to support lesson design, learning activities and assessment.

Purposes of Learning Activities	Artificial Intelligence (AI)	Multimedia Resources (Animations & Videos)	Mobile Devices	Datalogger and Sensors	Online Learning and Assessment Platforms	Computer Simulations
Visualisation and modelling of abstract concepts	✓	✓				✓
Inquiry-based exploration and conceptual understanding	✓		✓			✓
Practical work and data handling			✓	✓		✓
Online reading, practice and quizzes, and self-directed learning	✓	✓			✓	
Assessment for learning and feedback	✓				✓	

Pedagogical Considerations of Using AI in Biology

When applying AI (including GenAI) to support learning and teaching, teachers should strike an appropriate balance between AI-assisted learning, hands-on scientific investigations (including practical laboratory work), fieldwork, and other teacher-guided learning activities. Teachers are required to exercise professional judgement in determining the appropriate use of AI and to ensure that they continue to play the role of learning facilitators.

For learning and teaching materials designed with the assistance of GenAI, teachers should clearly indicate the AI-generated components and avoid practices that may compromise academic integrity. Teachers should verify the authenticity, accuracy and consistency of AI-generated content before use. Where AI tools are used to support assessment or feedback, teachers should conduct manual review and moderation to ensure assessment quality and uphold academic integrity.

Teachers should also foster students' awareness of the ethical and responsible use of AI, including an understanding of its limitations and potential inaccuracies. Students should be guided to evaluate AI-generated outputs critically, verify information using authoritative sources, and use AI as an assistive tool rather than a substitute for scientific reasoning.

Teachers should also consider the intended learning objectives, the nature of biological concepts (e.g. sub-microscopic processes, dynamic systems, cause-and-effect relationships), and the need to balance digital experiences with hands-on practical work and inquiry-based learning when selecting digital educational tools.

The Use of AI in Biology Lesson Setting

When planning Biology lessons, teachers should clearly define the learning objectives and consider how AI can be used to support students' engagement in scientific practices aligned with those objectives, such as applying biological concepts to novel problems, analysing and interpreting experimental data, and constructing explanations and evaluations.

When planning Biology lessons involving the use of AI, teachers should consider:

- the intended learning objectives and expected learning outcomes;
- how AI can support, rather than replace, students' conceptual understanding and inquiry;
- the provision of appropriate scaffolding and guidance for students' use of AI tools;
- learning strategies to consolidate understanding and promote knowledge transfer; and
- the balance between digital learning experiences and other teacher-guided learning activities, including practical laboratory work, inquiry-based experiments, reflective discussion on socio-scientific issues and scientific reasoning.

Example of Using Digital Educational Tools and AI in Classroom Design

AI tools can assist in visualising the abstract sub-microscopic and cellular world of Biology. With well-designed learning and teaching activities, teachers can create opportunities for students to link macroscopic phenomena (e.g. observable traits, physiological responses, or ecological patterns) with processes at the cellular, molecular, and sub-cellular levels through active, constructive and interactive learning. When designing AI-assisted activities, teachers should focus on helping students apply relevant prior knowledge and transfer their acquired understanding to novel problems, while critically evaluating AI-generated information.

Topic: Unit II Cellular Energetics

Learning outcomes:

- Explain the lock and key hypothesis for the action of enzymes, including the role of the active site and enzyme-substrate specificity.

Learning activities	The Use of Digital Educational Tools / AI
1. Teachers first guide students to predict and hand-draw the basic lock and key model, including the enzyme active site, substrate, and enzyme-substrate complex, with explanations based on shape complementarity and specificity.	No AI
2. Through teacher questioning and peer discussion, students extend their reasoning to consider how factors such as temperature, pH, and inhibitors might affect enzyme activity by influencing enzyme shape or active site configuration.	No AI
3. Students then upload their hand-drawn diagrams and explanations to a generative AI (GenAI) tool. With clear constraints set by the teacher, the AI is only allowed to identify possible error types (e.g. inaccuracies in depicting the active site or misunderstanding of induced fit aspects) and suggest checking steps, but not provide final answers or complete models.	Using GenAI to provide tailored feedback on students' answers
4. Students verify the AI feedback using authorised simulation tools (e.g. PhET simulations on enzyme action or related interactive models), discuss with peers, revise their work accordingly, and submit to teachers both original and revised versions as learning evidence.	Using other digital learning tools to assist learning

- As an extension, students apply the same AI-assisted approach to explain how environmental factors (e.g. temperature, pH, substrate concentration) influence the rate of enzymatic reactions (such as in digestion or photosynthesis) by relating changes in enzyme shape, active site accessibility, and reaction efficiency. Through peer discussion and reflection, students refine their understanding of sub-cellular models and strengthen scientific reasoning.

Annex 2

[A sub-section to be included in Chapter 3: Curriculum Planning of the Biology (S4-6) Curriculum and Assessment Guide]

Connections across Learning of Senior Secondary Science Subjects

In the course of the learning and teaching of Biology (S4-6), Chemistry (S4-6) and Physics (S4-6) curricula, students will encounter scientific inquiry skills and subject contents that are interconnected across science subjects. These shared learning elements are important components that constitute the nurturing of students' scientific literacy. Specifically, although these science curricula are offered as distinct elective subjects at the senior secondary level, they are underpinned by shared scientific principles and modes of inquiry in science. Students taking two or three science electives therefore experience reinforcement in science learning, as concepts and skills developed in one subject often deepen and extend student's understanding in another.

To enhance the coherence and depth of learning across Biology, Chemistry and Physics, this section highlights explicitly the common scientific inquiry skills and interrelated subject contents articulated in the respective curricula. By recognising these shared elements, teachers can adopt a more integrated approach to science teaching, not only reinforcing the shared scientific skills, but also developing students' understanding of science when students are engaged in the process and practice of science. Biology teachers should not focus solely on subject-specific knowledge within the Biology discipline, but should also consciously cultivate the shared scientific competences common to all science subjects. This shared emphasis supports progression from Science (S1-3) curriculum, strengthens coherence within the Science Education KLA, and equips students with the competencies required for evidence-based inquiry, critical evaluation of data, and informed decision-making in scientific and real-life contexts.

Common scientific inquiry skills across Biology (S4-6), Chemistry (S4-6) and Physics (S4-6) curricula

Experimenting, data processing and scientific reasoning skills are fundamental to Biology, Chemistry and Physics at the senior secondary level. Together, they form the foundation of scientific inquiry as emphasised in the Science Education Key Learning Area. These skills are progressively developed through Science (S1-3) curriculum and enable students to generate reliable empirical evidence, analyse data quantitatively and qualitatively, evaluate experimental limitations, and draw valid and evidence-based conclusions.

Through the practical tasks recommended in the respective Curriculum and Assessment Guides for the senior secondary science curricula, students experience the evidence-driven and systematic nature of

scientific investigation. The shared emphasis on scientific inquiry not only strengthens the learning of valued competences among the three science disciplines but also reinforces transferable skills such as critical thinking, problem-solving, and collaboration, while cultivating positive values and attitudes including integrity in data handling, commitment to safety and awareness of ethical considerations in scientific practice.

1. Experimenting skills

By conducting the recommended practical tasks set out in the respective Curriculum and Assessment Guides, ranging from structured practical work and inquiry to more open-ended investigative studies, students actively engage in the essential processes of scientific inquiry in a systematic and reflective manner, including observation, hypothesis formulation, experimental design, data collection, data interpretation, and conclusion drawing. Engaging in practical activities across Biology, Chemistry, and Physics enables students to both deepen subject-specific understanding and appreciate the common principles underlying scientific practice across disciplines, such as the tentative yet evidence-based nature of scientific knowledge, the importance of validity and reliability, and the role of creativity and perseverance in advancing understanding.

The following **experimenting skills** are commonly articulated across the three subjects, with clear progression from the junior secondary level:

E1 Planning and designing investigations
E2 Risk assessment and safe laboratory practices
E3 Selecting and handling apparatus and materials
E4 Controlling variables and ensuring reliability
E5 Accurate and precise measurement and observation
E6 Data collection and recording
E7 Evaluation and improvement of experiments

E1 Planning and designing investigations

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Formulate testable hypotheses or research questions based on observations or relevant prior scientific knowledge • Identify questions to study and make predictions • Select appropriate methods and justify experimental approaches • Identify independent, dependent, and control variables • Design logical and feasible procedures to address the research question • Plan and write experimental procedures	✓ Formulating a hypothesis based on observed phenomena ✓ Identifying independent variables, dependent variables and control variables ✓ Choosing from alternative experimental methods or improving the method for a scientific investigation

E2 Risk assessment and safe laboratory practices

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Carry out risk assessments for experiments / scientific investigations • Implement appropriate safety measures (e.g. use of personal protective equipment, proper handling of chemicals, high-voltage electrical equipment, or biological specimens) • Demonstrate responsible laboratory practice, including proper waste disposal, adherence to safety rules (e.g. always attending a heat source), and appropriate emergency procedures • Conduct investigations safely to collect valid and reliable data	✓ Using apparatus appropriately and safely

E3 Selecting and handling apparatus and materials

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Select apparatus and materials appropriate to the required precision, scale, and nature of the investigation • Use instruments and materials properly and competently • Handle materials efficiently to minimise waste and ensure experimental feasibility	✓ Using apparatus appropriately and safety

E4 Controlling variables and ensuring reliability

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Design controlled experiments to investigate relationships (correlational or causal) between variables • Identify potential confounding factors and minimise their effect • Use repeated trials and averaging measurements to reduce the effect of random errors • Assess reliability and suggest improvements to enhance experimental design	✓ Setting up a controlled experiment to identify causal relationships ✓ Identifying independent variables, dependent variables and control variables

E5 Accurate and precise measurement and observation

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Use measuring instruments correctly and read scales to appropriate precision • Distinguish between accuracy and precision • Make careful qualitative observations (e.g. colour change, precipitate formation, behavioural response, unexpected phenomena) • Comment on accuracy and precision in scientific measurements	✓ Making qualitative observations and recording quantitative measurements ✓ Commenting accuracy and precision in a scientific measurement

E6 Data collection and recording

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Collect sufficient and relevant data to address the research question • Record measurements with appropriate units and significant figures • Record raw data systematically in tables or structured formats • Perform initial data processing where appropriate (e.g. averaging or unit conversions) • Present data clearly to facilitate further analysis	✓ Making qualitative observations and recording quantitative measurements ✓ Using tables and graphs for organising and presenting data

E7 Evaluation and improvement of experiments

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Evaluate the feasibility, validity and reliability of experiments • Suggest ways to improve the feasibility, validity, and/or reliability of experiments • Identify limitations and sources of error in experiments • Propose refinements or alternative approaches for future studies	✓ Choosing from alternative experimental methods or improving the method for a scientific investigation

2. Data processing skills

After collecting data from experiments, students are required to process and analyse the data in order to draw valid conclusions to support or refute the set hypothesis. The fundamental knowledge and skills are developed in the Science (S1-3) curriculum. At the senior secondary level, these skills are further strengthened and applied with greater mathematical rigour and conceptual depth across Biology, Chemistry and Physics.

Annex 2

The following **data processing skills** are commonly articulated across the three science subjects, with clear progression from the junior secondary level:

D1 Use of SI unit, prefixes and derivation of units
D2 Significant figures and treatment of measurement errors
D3 Graphical presentation of relationships and functions
D4 Data analysis and interpretation

D1 Use of SI unit, prefixes and derivation of units

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Use SI units appropriately when expressing physical, chemical and biological quantities • Perform unit conversions accurately, including the use of prefixes and scientific notation • Derive and interpret compound units from base SI units where appropriate • Represent quantities with appropriate order of magnitude	✓ Using scientific notation, significant figures and ratio for expressing and comparing scientific data

D2 Significant figures and treatment of measurement errors

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Record measurements with appropriate precision according to the measuring instrument used • Express calculated results using an appropriate number of significant figures • Distinguish between accuracy and precision • Reduce the effect of random errors through repeated measurements and averaging • Identify anomalous results and evaluate their impact on reliability	✓ Using scientific notation, significant figures and ratio for expressing and comparing scientific data

D3 Graphical presentation of relationships and functions

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Select appropriate variables for the x- and y-axes based on the nature of the independent and dependent variables • Choose suitable scales and units, axis labels, and graph titles for clear and accurate graphical representation • Plot data accurately (by hand and/or using digital tools) to construct appropriate line graphs or scatter graphs, or other suitable graph types • Recognise and represent common mathematical relationships graphically	✓ Using tables and graphs for data analysis

D4 Data analysis and interpretation

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Perform data analyses to identify patterns, trends or relationships in the collected data • Draw appropriate best-fit lines or curves from graphical data, and use them to interpret trends, interpolate/extrapolate values or determine slopes/intercepts • Interpret graphical representations to identify patterns, relationships, anomalies, or limitations in the data • Relate graphical and numerical results to underlying scientific principles • Evaluate limitations of data and suggest improvements	✓ Using tables and graphs for data analysis ✓ Identifying outliers and handling data from repeated measurements to assess the uncertainty incurred

3. Scientific Reasoning skills

Scientific reasoning skills involve deductive, inductive and abductive reasoning as foundational processes, these are applied in the use, evaluation, and revision of scientific models and argumentations. Through such reasoning, students interpret empirical evidence, construct coherent scientific explanations, and critically evaluate claims and models. Progressively developed from the Science (S1-3) curriculum, these higher-order cognitive skills are central to scientific literacy as articulated in the Science Education Key Learning Area. In senior secondary Biology, Chemistry, and Physics, students apply scientific reasoning when analysing experimental data, evaluating the validity of conclusions, applying concepts to novel situations, and examining Science, Technology, Society and the Environment-related issues using evidence-based judgement.

The following **scientific reasoning skills** are commonly articulated across the three subjects, with clear progression from the junior secondary level:

R1 Scientific reasoning: deduction, induction and abduction
R2 Application of reasoning: scientific modelling and argumentation

R1 Scientific reasoning: deduction, induction and abduction

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Draw logical inferences from observations, experimental data or scientific information • Examine evidence and apply logical reasoning to draw valid conclusions • Make informed judgements when outcomes involve uncertainty or probability • Use inductive reasoning to generalise from specific observations or data to broader trends, patterns, conclusions, or models • Apply deductive reasoning to predict specific outcomes from a set of general observations or data and established laws, principles, theories, models, or established trends	✓ Using specific data to induce a general trend, conclusion or model ✓ Using a set of general observations, trend or model to deduce a specific result ✓ Making inference to the best possible explanation to the observed phenomenon ✓ Making informed decision based on the probability of phenomenon to be occurred

• Apply abductive reasoning to infer the most plausible explanation consistent with available evidence when multiple interpretations are possible • Recognise the appropriate contexts, strengths, and limitations of inductive, deductive, and abductive reasoning in scientific inquiry	

R2 Application of reasoning: scientific modelling and argumentation

Students studying Biology, Chemistry or Physics should be able to	Articulation with Science (S1-3) curriculum
• Apply appropriate scientific models to explain phenomena, interpret data, and predict outcomes in familiar and novel contexts • Evaluate the strengths, limitations, assumptions, and tentative nature of scientific models • Construct and present reasoned scientific arguments supported by empirical evidence, logical reasoning, and relevant scientific principles • Engage in scientific argumentation as a systematic process to analyse, explain, critique, or defend explanations of natural phenomena • Integrate new concepts or evidence into existing knowledge frameworks and apply them critically to new situations • Appreciate the evolutionary nature of scientific knowledge, where models and explanations are subject to revision based on accumulating evidence	✓ Using specific data to induce a general trend, conclusion or model ✓ Using a set of general observations, trend or model to deduce a specific result ✓ Making inference to the best possible explanation to the observed phenomenon ✓ Making informed decision based on the probability of phenomenon to be occurred

Related subject contents across Biology (S4-6), Chemistry (S4-6) and Physics (S4-6) curricula

Biology, Chemistry, and Physics are offered as distinct elective subjects at the senior secondary level. Nevertheless, they share many fundamental concepts and principles. Students who concurrently study two or three science subjects gain significant advantages in developing a more comprehensive and interconnected understanding of the unified nature of science. By exploring the common fundamental concepts, such as matter, energy and interactions governing the physical world from subatomic to universe scales, through different disciplinary perspectives, students reinforce and deepen their mastery across subjects, enabling them to apply knowledge flexibly in novel or real-life contexts. For example, understanding conservation of energy in Physics strengthens interpretation of enthalpy changes in Chemistry and energy flow in biological ecosystems, fostering more sophisticated and transferable conceptual understanding.

Furthermore, studying multiple science subjects promotes fluency in shared language and conventions. Students become more proficient in precise scientific terminology (e.g. mole, potential difference, activation energy), symbolic representations (e.g. equations, graphs, structural formulae), and quantitative tools (e.g. significant figures, unit conversions, error estimation). This shared use of scientific language, notation, and representational practices reduces barriers between subjects, enhances communication of science ideas, and strengthens students' overall scientific literacy.

Making these cross-disciplinary connections explicit enables students to develop a more integrated and coherent understanding of scientific phenomena. More specifically, students taking two or three science electives will recognise that concepts encountered in one science subject often provide explanatory frameworks for understanding phenomena in another, thereby deepening conceptual understanding, and promoting the application of knowledge across contexts.

Annex 2

The following table provides examples of related contents of Biology, Chemistry and Physics curricula, illustrating how core ideas, such as energy transformations, the structure of matter, particle interactions, radiation, and the relationship between structure and function, are developed and applied in different disciplinary contexts.

Examples of related subject contents of Biology, Chemistry and Physics:

Biology	**Chemistry**	**Physics**
Energy flow in ecosystems; energy transformations in cellular respiration and photosynthesis; Regulation of body temperature	Enthalpy changes in chemical reaction	Temperature, heat and internal energy; Heat transfer process; Change of state; Law of conservation of energy in a closed system
Gas exchange in humans and plants	Mole concept; Avogadro's Law; Molar volume	Gas laws
Factors affecting rate of enzymatic reactions; Diffusion and osmosis across cell membranes	Rate of reaction	Kinetic theory
Effects of light intensity on photosynthesis; Light absorption in photosynthetic pigments	IR spectroscopy	EM wave spectrum; Intensity
Nerve impulse transmission	Chemical cells; Electrolysis	Electric circuit
Enzyme-substrate binding; water properties	Bond polarity; Intermolecular forces	Electrostatics; Scalars and vectors
Structure and chemical bonding in biomolecules (e.g., DNA nucleotides, proteins)	Atomic structure; Subatomic particles; Isotopes	Atomic model; Radioactive decay; Isotopes
Use of resources in ecosystems		Fossil fuels and carbon compounds

Mathematical skills across Biology (S4-6), Chemistry (S4-6) and Physics (S4-6) curricula

A strong foundation in mathematics is essential for the study of Biology, Chemistry, and Physics at senior secondary level, as many mathematical skills are shared or closely related across the three disciplines. These include algebraic manipulation and formula application, data handling and graphical analysis, as well as application of geometry and trigonometry. Examples of related mathematical skills of Biology, Chemistry and Physics are tabulated below for reference:

Mathematical skills	**Contexts in Science Subjects (Examples)**
Manipulation of equations and functions	Biology • Apply equations related to microscopy (e.g. magnification = image size / actual size). Chemistry • Solve algebraic equations (e.g. rate = k[reactant1]^{x}[reacton2]^{y}) • Perform calculations involving logarithms (e.g. pH = -log[H^{+}], Arrhenius equation) Physics • Derive and apply equations to solve problems for topics such as mechanics, electricity and magnetism, and quantum physics
Handling data and use of units	Biology • Convert between metric units (e.g. millimeters to micrometers) when calculating the sizes of sub-cellular structures • Apply appropriate measurement units when quantifying environmental conditions Chemistry • Express physical quantities (e.g. molecular mass, concentration) using appropriate units and how they can be inter-converted • Calculate a mean titre Physics • Perform dimensional analysis by converting and matching SI units • Apply the concept of order of magnitude and significant figures in experimental measurements
Use and interconversions of ratios, fractions and percentages	Biology • Calculate percentages to determine the efficiency of energy transfer between trophic levels Chemistry

	• Determine empirical formulae and molecular formulae from compositions by mass and molar masses Physics • Find the efficiency of transformer, electrical appliance, and machines
Constructing and interpreting graphs	Biology • Plot graphs to determine physical properties of biological tissues • Interpret curves to deduce physiological changes over time or distance Chemistry • Determine the activation energy of a chemical reaction • Calculate enthalpy changes from experimental results Physics • Plot and analyse graphs for physical laws • Interpret the physical meaning of slope and intercepts
Application of geometry and trigonometry	Biology • Understand three-dimensional structures of biomolecules Chemistry • Predict and draw three-dimensional diagrams to represent molecular shapes Physics • Apply addition of vector to find resultant vector and resolve a vector into components (e.g. acceleration, force) • Apply dot product and cross product in mechanics (e.g. work done), and electricity and magnetism (e.g. magnetic force)

Students who study two or three science subjects benefit significantly as they can reinforce these common mathematical skills, leading to deeper conceptual understanding and greater fluency in applying mathematics to solve scientific problems. This advantage is further amplified when students also take Mathematics Extended Part (Module 1 or 2) alongside the science subjects, as the study of extended mathematics enables them to engage with more advanced science topics at a deeper level. For example, knowledge of calculus from Module 1 or 2 equips students with a stronger grasp of concepts such as rate of change and the relationship between the area under a curve and physical quantities in the kinematics topic in Physics. Such synergy not only supports but also extends learning across all three subjects.

Annex 3

Summary of Proposed Updates to Biology Curriculum Content

Update Direction	Proposed Revisions to Curriculum Content	Rationale
Enhancing vertical articulation with Junior Secondary Science	• Delete the topic "Sense Organs". Learning content on the eye and ear has already been incorporated into Unit 12 "Light and Sound" of the updated Science (S1–S3) curriculum. • Delete the topic "Molecules of Life" (involving biological tests of food substances and basic building blocks) and the topic "Teeth and Dentition". Their learning content has already been incorporated into Unit 11 "A Healthy Body" of the updated Science (S1–S3) curriculum.	• Streamline the biology-related learning elements in the Science (S1–S3) curriculum so as to strengthen coherence and progression between the junior secondary and senior secondary stages.
Integrating the Compulsory Part and Elective Part	• From the former Elective Part E1 "Human Physiology: Regulation and Control": water regulation, temperature regulation and regulation of gas composition in the blood are incorporated into Unit 5 "Human Physiology (II)"; hormonal control of the reproductive cycle is incorporated into Unit 7 "Continuity of Life". • Former Elective Part E2 "Applied Ecology" is incorporated into Unit 12 "Conservation and Sustainable Development". • From former Elective Part E3 "Microorganisms and Humans": microbiology and the use of microorganisms are incorporated into Unit 10 "Biotechnology"; diseases caused by microorganisms are incorporated into Unit 11 "Health and Diseases". • Former Elective Part E4 "Biotechnology" is incorporated into Unit 10 "Biotechnology", and is also integrated into parts of Unit 8 "Genetics" and Unit 12 "Conservation and Sustainable Development".	• Assist teachers in integrating the teaching of related topics in a more coherent manner to reduce overlapping of teaching content, thereby releasing some lesson time.

Update Direction	Proposed Revisions to Curriculum Content	Rationale
Trimming, fine-tuning and re-sequencing of topics / sub-topics	Deletion of the following sub-topics / learning outcomes: • Molecules of Life - Relate the importance of water, inorganic ions and biomolecules (building blocks and functions of carbohydrates, lipids and proteins) to life. - Carry out common biochemical tests (e.g. Benedict's test, iodine test, grease-spot test and different types of test papers) to identify some biomolecules in living tissues. • Life processes in animals - Understand the structure and function of dentition and mastication in feeding. • Coordination and response - Understand the roles of sense organs and receptors in detecting environmental changes. - Relate the structures of the main parts of the eye (rods, cones, etc.) to vision. - Explain the causes of eye defects (long-sightedness, short-sightedness and colour blindness). - Describe how spectacles correct long-sightedness and short-sightedness, and know surgical methods of vision correction. - Relate the structures of the main parts of the ear to hearing. - Understand the importance of phototropism in plants, the mechanisms of phototropic responses of roots and shoots, and the role of auxins. • Biodiversity and evolution - Appreciate that there are different explanations for the origin of life. • Human impact on the environment	• Some learning content has already been incorporated into the updated Science (S1–S3) curriculum. • Create space for the integration of the Compulsory and Elective Parts.

Update Direction	Proposed Revisions to Curriculum Content	Rationale
	- Evaluate the effects of rapid population growth and its control (the need for population control). • Global issues - Understand the causes and problems related to global environmental issues (including discussion of acid rain). • Harmful effects of microorganisms - Understand the causes of food-borne diseases and food poisoning. - Understand biological deterioration caused by microorganisms in daily life.	
	Re-arrangement of the order of topics and sub-topics: • Certain topics under "Ecosystems" (e.g. population interactions, reproductive strategies, application of genetic variation at the population level) are incorporated into "Organisms and their Environment"; other topics under "Ecosystems" (including species conservation, habitat conservation and measures for sustainable development) are incorporated into "Conservation and Sustainable Development". In the sequencing of topics, "Conservation and Sustainable Development" is placed after "Biotechnology". • The topics "Cell cycle and division" and "Reproduction, growth and development" are incorporated into "Continuity of Life"; in the sequencing of topics, these topics are placed after "Organisms and their Environment".	• Incorporating the "Ecosystems" topics separately into "Organisms and their Environment" and "Conservation and Sustainable Development", and placing "Conservation and Sustainable Development" after "Biotechnology", allows students to accumulate diverse prior knowledge so as to deepen their understanding of the interconnections among science, technology and the environment. • Incorporating the topics "Cell cycle and

Update Direction	Proposed Revisions to Curriculum Content	Rationale
		division" and "Reproduction, growth and development" into "Continuity of Life" enhances the coherence of teaching.
	Fine-tuning of the learning outcomes of the following topics: • Cellular Energetics - Respiration: as an example of a catabolic process - Photosynthesis: as an example of an anabolic process • Human Physiology (I) - Excretion in humans • Organisms and their Environment - Interactions in woodland ecosystems • Evolution and Biodiversity - Biodiversity and biological classification. • Conservation and Sustainable Development - Local conservation case study: Mai Po and Inner Deep Bay wetlands.	• Make the existing learning objectives and learning outcomes clearer. • Add learning outcomes built on prior knowledge to strengthen students' understanding and consolidate their learning.
	Enrichment of the following sub-topics / learning outcomes: • Human Physiology (II) - Case study: Human physiology of exercise • Genetics - Genes and genomes - DNA replication, transcription and translation • Biotechnology - Techniques in molecular biology - Applications of genetic engineering in medicine and agriculture • Health and Diseases - Cancer	• Link the frontier developments in biotechnology with daily life. • Strengthen students' awareness of personal health and the concepts of, and sense of responsibility for, sustainable development.

Update Direction	Proposed Revisions to Curriculum Content	Rationale
	- Prevention of infectious diseases - Case study of bacterial disease: Tuberculosis - Case study of viral disease: Influenza. • Conservation and Sustainable Development - Climate change. - Food security and sustainable agriculture. - Case study: Growing soybean in marginal lands.	
Strengthening scientific inquiry skills	• A new Unit 13 "Scientific Investigations" (20 hours) is added. • This unit lists the key learning elements of scientific inquiry. Teachers may select from them and integrate them into the practical activities of different units. At the same time, the suggested learning and teaching activities in each unit include suggestions for inquiry-based practical activities (e.g. "design and conduct experiments") for teachers' reference.	• Provide students with sufficient learning experiences in scientific inquiry to strengthen their scientific inquiry abilities.

Membership of the Working Group on the Review of the Biology Curriculum and Assessment

(From Aug 2020 to Jan 2025)

Chairperson:	Prof CHAN Kam-ho
Members:	Mr CHAN Ka-loi Mr CHAN Pat-chun (Up to Feb 2023) Mr CHENG Yuen-shan Prof CHEUNG Hiu-tung, Tom Prof CHEUNG Siu-gin Ms CHOW Chi-yui (Up to July 2022) Mr CHUI Hing-wa (Up to August 2023) Mr IP Tai-man Dr LAU Sui-yee Dr MA Yin-nin Prof WONG Kam-bo Dr YUE Ying-kit
Ex-officio Members:	Mr SO Chi-shing, Jason (EDB) Mr TSUI Chi-shing, Ben (HKEAA)
Secretary:	Ms YAU Pui-yan, Cecilia (EDB)

Membership of the CDC-HKEAA Committee on Biology

(From September 2023 to August 2025)

Chairperson:	Dr LAU Sui-yee
Members:	Dr LI Wai-chin Prof LO Sze-chung Clive Prof WONG Kam-bo Prof WU Ruohao, Angela Dr YUE Ying-kit, Patrick Ms CHEUNG Man-lai Mr KO Ka-ho Ms LAI Kam-fung Dr LEE Lit-hong Dr SUEN Ka-chun
Ex-officio Members:	Mr SO Chi-shing, Jason (EDB) (Up to May 2025) Mr TSUI Chi-shing, Ben (HKEAA) (Up to Aug 2024) Mr CHAN Ka-loi (HKEAA) (From Sep 2024)
Secretary:	Ms YAU Pui-yan, Cecilia (EDB)

Membership of the CDC-HKEAA Committee on Biology

(From September 2025 to August 2027)

Chairperson:	Dr LI Wai-chin	
Members:	Prof CHAN Ho-yin, Edwin	
	Prof CHIU Man-ying	
	Prof LO Sze-chung, Clive	
	Prof WU Ruohao, Angela	
	Ms CHEUNG Man-lai	
	Mr KO Ka-ho	
	Ms LAI Kam-fung	
	Mr LAU Wai-ching	
	Dr LEE Lit-hong	
	Mr MA Chi-chung	
	Dr SUEN Ka-chun	
Ex-officio Members:	Mr TONG Wai-ming, Ralf	(EDB)
	Mr CHAN Ka-loi	(HKEAA)
Secretary:	Dr Jenny KWAN	(EDB)