# BIOLOGY SYLLABUS

## Pre-University

### Higher 1

### Syllabus 8876

Implementation starting with
2020 Pre-University One Cohort



Ministry of Education
SINGAPORE

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# 1. INTRODUCTION

## 1.1 BACKGROUND

**Design of the A-Level science curriculum**

As scientific and technological advances influence and impact how we live, communicate and interact with each other, it is important to offer a science education that develops in individuals knowledge of the core ideas in science and an understanding of the practices associated with scientific inquiry, which will enable them to make decisions on science-related issues and challenges brought about by these advances. To develop such individuals, research in science education has shown that there is a need to strike a balance between teaching the products of science (e.g. core ideas, theories, and models), the processes of science and the nature of science. These products, processes and nature of science have been articulated in the revised H2 science curriculum. The H1 science curriculum, which is designed as a subset of H2 science, will also incorporate these key features.

**Purpose of H1 science curriculum**

While H2 science develops in our students the disciplinary understanding, skills and attitudes necessary for further studies in the subject and related fields, H1 science is designed to broaden students' learning that will support the development of scientific literacy. This is especially important for future citizens in an increasingly technologically-driven world and for leaders of the country to be equipped to make informed decisions based on sound scientific knowledge and principles about current and emerging science-related issues which are important to self, society and the world at large (for example, in appreciating the energy constraints faced by Singapore, or in understanding the mechanisms involved in epidemics).

**Key changes to H1 science curriculum**

The key changes to the H1 science curriculum are in tandem with the changes in the H2 science curriculum. Namely, the use of Core Ideas to frame the teaching and learning of science, and the introduction of the Practices of Science to place emphasis on science as a way of knowing and doing, beyond viewing it as an acquisition of a body of knowledge. Like H2 science, H1 science also encourages the use of real-world contexts in teaching and learning, and in using a wider range of pedagogies through Learning Experiences.

**Differences between H2 and H1 science curriculum**

The Learning Experiences outlined in H2 science are largely relevant and applicable to H1 science. However, the actual choice of pedagogy and Learning Experiences would need to be carefully adapted and designed to suit the teaching for H1 science, especially in the area of science practical activities. There would be less emphasis on developing students' proficiency in handling equipment and in carrying out various laboratory tests and techniques. Instead, the focus of science practical experiences will be on developing students' scientific knowledge and providing opportunities for students to understand the evidence-based nature of scientific knowledge.

The Practices of Science is a key feature in H1 science where greater emphasis would be placed on the development of those components that will enable students to become scientifically literate consumers and citizens who can use scientific understanding to explain and make informed choices concerning science-related issues. In particular, opportunities should be given for students to be engaged in discussion of important socio-scientific issues, such as the impact of climate change, the safe and responsible use of materials and the potential benefits and risks associated with the use of nuclear energy.

## 1.2 Purpose and Value of Biology

In Singapore, biology education from the primary to the A-Level has been organised as a continuum in the following manner:

a. From Primary 3 to 6, students learn about how life works at the systems level;
b. From Lower Secondary science to O-Level Biology, students learn about how life works at the physiological level; and
c. At the A-Level, students learn about how life works at the cellular and molecular level while understanding the implications on macro levels.

The Biology syllabus is developed as a seamless continuum from the O-Level to the A-Level, without the need for topics to be revisited at the A-Level. The O-Level syllabus is foundational and thus should provide the necessary background for study at the A-Level. Students who intend to offer H1 Biology will therefore be assumed to have knowledge and understanding of O-Level Biology, either as a single subject or as part of a balanced science course.

Many new and important fields of biology have emerged through recent advancements in life sciences. Vast amounts of knowledge have been generated as evident from the sprouting of scientific journals catering to niche areas of research. As such, this syllabus refines and updates the content knowledge of the previous syllabus (9648) so that students can keep themselves up to date with knowledge that is relevant for their participation in a technology-driven economy.

The value of learning H1 Biology ultimately hinges on the development of a scientific mind and disposition while addressing the broader questions of what life is and how life is sustained. The Science Curriculum Framework developed by MOE elaborates on the development of the scientific mind and disposition. Through the study of the H1 Biology course, students should be prepared for life science-related courses at university and, consequently, careers that are related to this field.

### 1.3 Aims

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

1. provide students with an experience that develops their interest in biology and builds the knowledge, skills and attitudes necessary for further studies in related fields;

2. enable students to become scientifically literate citizens who are well-prepared for the challenges of the 21st century;

3. develop in students the understanding, skills, ethics and attitudes relevant to the Practices of Science, including the following:
    - understanding the nature of scientific knowledge
    - demonstrating science inquiry skills
    - relating science and society

4. address the broader questions of what life is and how life is sustained, including:
    - understanding life at the cellular and molecular levels, and making connections to how these micro-systems interact at the physiological and organismal levels
    - recognising the evolving nature of biological knowledge
    - stimulating interest in and demonstrating care for the local and global environment.

### 1.4 Practices of Science

Science as a discipline is more than the acquisition of a body of knowledge (e.g. scientific facts, concepts, laws, and theories); it is a way of knowing and doing. It includes an understanding of the nature of scientific knowledge and how this knowledge is generated, established and communicated. Scientists rely on a set of established procedures and practices associated with scientific inquiry to gather evidence and test their ideas on how the natural world works. However, there is no single method and the real process of science is often complex and iterative, following many different paths. While science is powerful, generating knowledge that forms the basis for many technological feats and innovations, it has limitations.

Teaching students the nature of science helps them to develop an accurate understanding of what science is and how it is practised and applied in society. Students should be encouraged to consider relevant ethical issues, how scientific knowledge is developed, and the strengths and limitations of science. Teaching the nature of science also enhances the students' understanding of science content, increases their interest in science and helps show its human side. Science teaching should emphasise *how* we know as well as *what* we know.

Understanding the nature of scientific knowledge, demonstrating science inquiry skills and relating science and society are the three components that form our Practices of Science. Students' understanding of the nature and limitations of science and scientific inquiry are developed effectively when the practices are taught in the context of relevant science content. Attitudes relevant to science such as inquisitiveness, concern for accuracy and precision, objectivity, integrity and perseverance are emphasised.

The curriculum provides opportunities for students to reflect how the Practices of Science contribute to the accumulation of scientific knowledge. Students are encouraged to think about the 'whys' when planning and conducting investigations, developing model or engaging in scientific arguments. Through such reflection, they can come to understand the importance of each practice and develop a nuanced appreciation of the nature of science.

The *Practices of Science* comprise three components:

A. Understanding the nature of scientific knowledge
B. Demonstrating science inquiry skills
C. Relating science and society

**A. Understanding the Nature of Scientific Knowledge**

- A1. Understand that science is an evidence-based, model-building enterprise concerned with the natural world
- A2. Understand that the use of both logic and creativity is required in the generation of scientific knowledge
- A3. Recognise that scientific knowledge is generated from consensus within the community of scientists through a process of critical debate and peer review
- A4. Understand that scientific knowledge is reliable and durable, yet subject to revision in the light of new evidence

**B. Demonstrating Science Inquiry Skills**

- B1. Identify scientific problems, observe phenomena and pose scientific questions/hypotheses
- B2. Plan and conduct investigations by selecting the appropriate experimental procedures, apparatus and materials with due regard for accuracy, precision and safety
- B3. Obtain, organise and represent data in an appropriate manner
- B4. Analyse and interpret data
- B5. Construct explanations based on evidence and justify these explanations through sound reasoning and logical argument
- B6. Use appropriate models to explain concepts, solve problems and make predictions
- B7. Make decisions based on evaluation of evidence, processes, claims and conclusions
- B8. Communicate scientific findings and information using appropriate language and terminology

**C. Relating Science and Society**

- C1. Recognise that the application of scientific knowledge to problem solving could be influenced by other considerations such as economic, social, environmental and ethical factors
- C2. Demonstrate an understanding of the benefits and risks associated with the application of science to society
- C3. Use scientific principles and reasoning to understand, analyse and evaluate real-world systems, as well as to generate solutions for problem solving

**Developing 21st Century Competencies through the Learning of Science**

To prepare our students for the future, a Framework for 21st Century Competencies (21CC) and Student Outcomes was developed by MOE (see **Figure 1.1**). This 21CC framework is meant to equip students with the key competencies and mindsets to be successful in the 21st century, even as we maintain our strong fundamentals in teaching and learning.

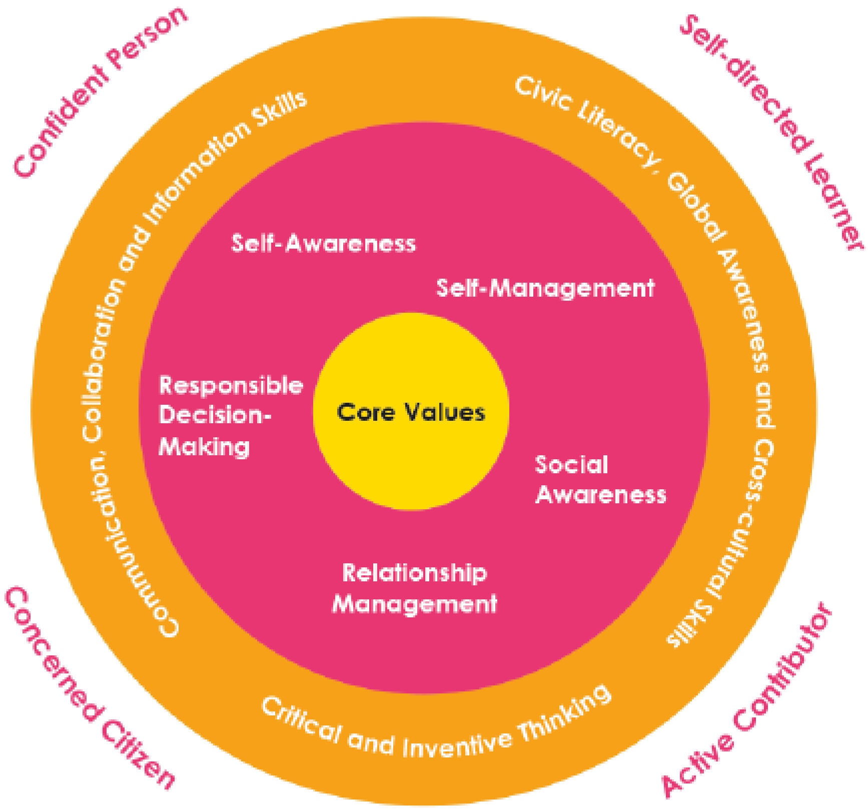


**Figure 1.1**: Framework for 21st Century Competencies and Student Outcomes

The features and intent of the Practices of Science are consistent with the emphasis on developing 21CC in our students. These are explicitly articulated in the syllabus to encourage teachers to embed them as learning objectives in their lessons.

The development of 21CC should not be seen as separate from the learning of science. The features of scientific inquiry, such as the processes of scientific investigation, reasoning, modelling and problem solving support a student's development of 21CC. The students' understanding of the nature and limitations of science and scientific inquiry are developed effectively when scientific practices are taught in the context of relevant science content. Engaging our students in deep disciplinary learning in science will help to develop 21CC and promote the process of learning for transfer to other areas of life.

## 1.5 H1 Biology Curriculum Framework

The rapid progress in the field of life sciences poses a challenge for biology education, especially in terms of designing a framework that integrates fundamental knowledge, skills and attitudes. With this in mind, this syllabus has adopted a framework that will chart a new direction for biology education. **Figure 1.2** below provides an overview of this framework.

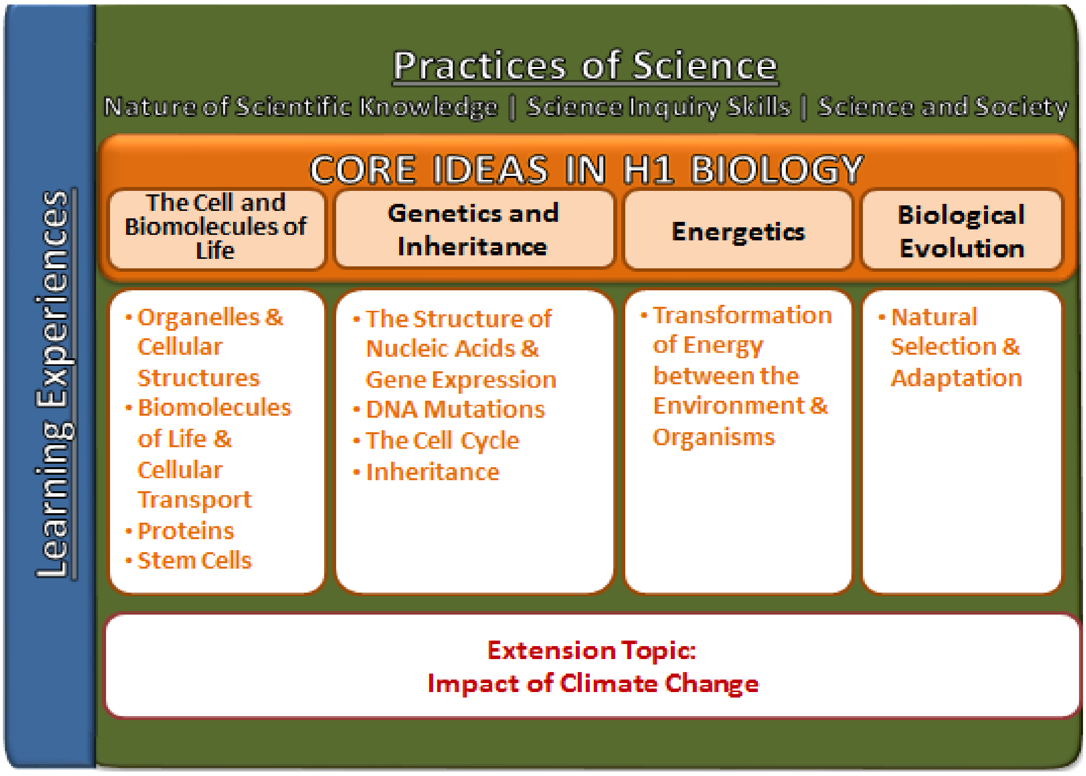


**Figure 1.2**: Overview of the H1 Biology Curriculum Framework

The Practices of Science are common to the natural sciences of Physics, Chemistry and Biology. These practices highlight the ways of thinking and doing that are inherent in the scientific approach, with the aim of equipping students with the understanding, skills, and attitudes shared by the scientific disciplines, including an appropriate approach to ethical issues.

The content in this H1 Biology teaching and learning syllabus is organised around four Core Ideas of biology. For each Core Idea, pertinent, open-ended guiding questions are listed to help students frame the concepts and promote inquiry, while narratives allow links between concepts – both within and between Core Ideas – to be made.

Besides the Core Ideas, this H1 Biology teaching and learning syllabus features an Extension Topic. The Extension Topic is based on important emerging biological issues impacting both the local and global contexts. It requires students to demonstrate assimilation of the Core Ideas and extend their knowledge and understanding to real-world challenges. Furthermore, the Extension Topic will equip students with the necessary knowledge and process skills to make informed decisions about scientific issues.

Students are expected to study all four Core Ideas and the Extension Topic.

# 2. CONTENT

### 2.1 Core Idea 1: The Cell and Biomolecules of Life

This Core Idea entails the study of cells which are the basic units of life.

Students can frame their learning using the following questions:

- Why is a cell the basic unit of life and how does it promote continuity of life?
- How is the knowledge of this basic unit crucial in understanding life?
- How are the structures of biomolecules related to their functions?
- How do cells regulate the movement of substances into and out of themselves, and what are the functions of such movements?
- How do cells of prokaryotes and eukaryotes, cells of plants and animals, and cells of unicellular and multicellular organisms differ?

**Sub-cellular structures provide the means to drive cellular processes**

The understanding of how cellular structures facilitate specific cellular processes is fundamental to explaining how life works. The cell theory states that the cell is the smallest and most basic unit of life and that cells are derived from existing cells. Understanding the role of cellular organelles (such as the nucleus, ribosome, chloroplast and mitochondrion) and cellular structures (for example, the cytoskeleton) will help in understanding the concept of how structure relates to function.

There are significant differences between cells of prokaryotes and eukaryotes. Using bacteria as a model, the nucleoid is not enclosed by any membrane. Plasmids may be present as extra-chromosomal DNA. Membrane-bound organelles, such as mitochondria and endoplasmic reticulum, are absent. Prokaryotic ribosomes are different from eukaryotic ribosomes. Some bacterial cells have cell walls that comprise peptidoglycan rather than cellulose. Within the eukarya domain, the cell model of plants is also different from that of animals. Unlike unicellular organisms which merely undergo cellular division, cells of multicellular organisms undergo division and differentiation to allow them to carry out their specific functions.

**Biomolecules make up cells and cells regulate many cellular processes, including the movement of substances into and out of themselves, through membranes**

The different classes of biomolecules (carbohydrates, lipids, proteins and nucleic acids) function as molecular building blocks for macromolecules to be assembled. Nucleic acids, which include DNA and RNA, are made from monomers known as nucleotides. Biomolecules are important components of cell structures, including membranes which are made up of phospholipids, cholesterol, carbohydrates and proteins.

Cells need to regulate the movement of substances into and out of themselves. Substances such as water, oxygen, glucose and minerals are important in the synthesis of new molecules and important cellular processes. According to the fluid mosaic model of the cell membrane, membranes are selectively permeable due to the nature of the phospholipids and proteins from which they are made. The movement of different molecules depends on the nature of the substances through transport processes such as osmosis, diffusion and active transport. Membranes give cells the important ability to create and maintain internal environments that are different from external environments.

Eukaryotic cells also contain internal membrane structures that partition the cell into specialised compartments so that cellular processes can occur with optimal activity e.g. chloroplasts and mitochondria. The endomembrane system, including the rough and smooth endoplasmic reticulum and Golgi body, is responsible for protein processing and vesicular transport within the cell. Prokaryotes generally lack such membrane-bound organelles and endomembrane systems; yet they survive and reproduce.

**Proteins play significant roles in cells**

Proteins play a variety of significant roles in cells including structural, transport, enzymatic and signalling functions. They are essential for biological processes and functions, such as protein synthesis, chemiosmosis, cell signalling, blood glucose homeostasis and immunology. Protein structure can be affected by temperature and pH. Enzymes are an important group of proteins that control many biological reactions. The functions of these proteins will be revisited in the other core ideas.

**Stem cells have the potential to divide and differentiate into different cell types**

Following fertilisation, a single-cell zygote develops into a multicellular organism. The zygote can replicate its DNA, divide its nucleus and divide into two genetically-identical cells. Cell potency describes a cell's ability to differentiate into other cell types. The zygote and cells formed from the first few cell divisions during embryonic development (up to the eight-cell stage) produce totipotent cells. Beyond the eight-cell stage, one of the two daughter cells remains undifferentiated, retaining the ability to divide indefinitely as a stem cell, while the other daughter cell differentiates. After the eight-cell stage, the cells begin to specialise into pluripotent stem cells. Pluripotent stem cells undergo further specialisation into multipotent cells, which can further differentiate to become unipotent stem cells.

Environmental signals trigger the differentiation of a cell into a more specialised form. Cell differentiation involves changing or regulating the expression patterns of genes. Each specialised cell type in an organism expresses a subset of all the genes that constitute the genome and this expression is regulated by various mechanisms resulting in differential gene expression of the same genome.

It is important to recognise that a cell is dynamic in nature and not a static structure. At any point of time, numerous activities are occurring in the cell. In a plant cell, photosynthesis and respiration can be occurring simultaneously. This causes biochemical changes in the cytoplasm of the plant cell. If it is necessary to produce more chlorophyll pigments or increase the amount of cellulose, the rate of protein synthesis in those biochemical pathways will increase.

## A. Organelles and Cellular Structures

This concept discusses the typical cell model of prokaryotes and eukaryotes, including plants and animals. A strong understanding of the structure of the following organelles and cellular structures in relation to their function is necessary: rough and smooth endoplasmic reticulum, Golgi body, mitochondria, ribosomes, lysosomes, chloroplasts, cell surface membrane, nuclear envelope, centrioles, nucleus and nucleolus.

| **Learning Outcomes** | |
|---|---|
| (a) | Outline the cell theory with the understanding that cells are the smallest unit of life, all cells come from pre-existing cells, and living organisms are composed of cells. |
| (b) | Interpret and recognise drawings, photomicrographs and electronmicrographs of the following membrane systems and organelles: rough and smooth endoplasmic reticulum, Golgi body, mitochondria, ribosomes, lysosomes, chloroplasts, cell surface membrane, nuclear envelope, centrioles, nucleus and nucleolus. |
| (c) | Outline the functions of the membrane systems and organelles listed in (b). |
| (d) | Describe the structure of a typical bacterial cell (small and unicellular, peptidoglycan cell wall, circular DNA, 70S ribosomes and lack of membrane-bound organelles). |

## B. Biomolecules of Life and Cellular Transport

This concept focuses on how the structures of biomolecules give rise to properties that allow these biomolecules to carry out their functions. One of these functions involves regulating the transport of substances into and out of the cell. This regulation is afforded by the properties of the cell membrane which comprises phospholipids and proteins. Regulation of the movements is important for several biochemical processes to occur.

| Learning Outcomes |
|---|
| (e) Describe the structure and properties of the following monomers:<br>i. α-glucose and β-glucose (in carbohydrates)<br>ii. glycerol and fatty acids (in lipids)<br>iii. amino acids (in proteins) (knowledge of chemical formulae of specific R-groups of different amino acids is not required)<br><br>(f) Describe the formation and breakage of the following bonds:<br>i. glycosidic bond<br>ii. ester bond<br>iii. peptide bond<br><br>(g) Describe the structures and properties of the following biomolecules and explain how these are related to their roles in living organisms:<br>i. starch (including amylose and amylopectin)<br>ii. cellulose<br>iii. triglyceride<br>iv. phospholipid<br><br>(h) Explain the fluid mosaic model and the roles of the constituent biomolecules (including phospholipids, proteins, glycolipids, glycoproteins and cholesterol) in cell membranes.<br><br>(i) Outline the functions of membranes at the surface of cells and membranes within the cell.<br><br>(j) Explain how and why different substances move across membranes through simple diffusion, osmosis, facilitated diffusion, active transport, endocytosis and exocytosis. |

## C. Proteins

Proteins play a variety of roles in structural, transport, enzymatic and signalling functions. This concept focuses on the structure and properties of proteins and how temperature and pH may contribute to the denaturation of proteins. Similarly, enzymes and the rate at which they catalyse reactions are influenced by temperature and pH of the environment. The effects of other factors such as enzyme and substrate concentration on the rate of reaction are also explored in this concept.

| Learning Outcomes |
| --- |
| (k) Explain primary structure, secondary structure, tertiary structure and quaternary structure of proteins, and describe the types of bonds that hold the molecule in shape (hydrogen, ionic, and disulfide bonds, and hydrophobic interactions). |
| (l) Explain the effects of temperature and pH on protein structure. |
| (m) Describe the molecular structure of the haemoglobin protein and explain how its structure relates to its function in transport. (Knowledge of details of the number of amino acids and types of secondary structures present is not required.) |
| (n) Explain the mode of action of enzymes in terms of an active site, enzyme-substrate complex, lowering of activation energy and enzyme specificity using the lock-and-key and induced-fit hypotheses. |
| (o) Investigate and explain the effects of temperature, pH, enzyme concentration and substrate concentration on the rate of an enzyme-catalysed reaction by measuring rates of formation of products (e.g. measuring gas produced using catalase) or rate of disappearance of substrate (e.g. using amylase, starch and iodine). |

## D. Stem Cells

This concept highlights the diversity in cell type and the morphology in an organism. In an organism, all cells except the gametes are genetically identical. Yet, a liver cell, a rod cell in the eye and an epithelial cell in the ileum differ significantly in terms of morphology and function due to differential gene expression. The same genome gives rise to a wide range of cells which further form tissues, organs and systems in an organism.

The ability of stem cells to divide and their potential for self-renewal allows for growth. Stem cells replace cells that die or are damaged. During embryogenesis, cell division and differentiation allow the development of an entire organism *in utero* from a single-cell zygote.

Stem cells hold great potential as medical treatments. Haematopoietic stem cells are used in blood marrow transplants in cancer treatments. Skin stem cells are used to culture skin cells to treat patients with massive burns. Ethical debates over the use of stem cells are primarily concerned with the use of embryonic stem cells. The use of adult stem cells faces fewer of these ethical issues.

| **Learning Outcomes** |
| --- |
| (p) Describe the unique features of stem cells, including zygotic stem cells, embryonic stem cells and blood stem cells, correctly using the terms:<br>i. totipotency (e.g. zygotic stem cells)<br>ii. pluripotency (e.g. embryonic stem cells)<br>iii. multipotency (e.g. blood stem cells) |
| (q) Explain the normal functions of stem cells in a living organism, including embryonic stem cells and blood stem cells. |
| (r) Discuss the ethical implications of the application of stem cells in research and medical applications and how human induced pluripotent stem cells (iPSCs) overcome some of these issues (procedural details of how iPSCs are formed are not required). |

## 2.2 Core Idea 2: Genetics and Inheritance

This core idea helps make sense of the transition from molecular to organismal levels. It provides the molecular basis to the understanding of how variation in populations arises and this is important in the study of biological evolution. At the cellular level, expression of genes involves structures such as the nucleus, endoplasmic reticulum and ribosome. Many essential products of gene expression are enzymes involved in biochemical pathways which control physiological functions. As such, mutation of genes may give rise to dysfunctional proteins which in turn could result in diseases. Sickle cell anaemia and cancer are some examples of genetic diseases.

Students can frame their learning using the following questions:

- How does the genetic make-up of an organism and the environment influence the organism's appearance, behaviour and survival?
- How does the inheritance of genetic information ensure the continuity of humans as a species?

**Heritable information, in the form of DNA (and in some cases RNA), provides for continuity of life**

Genetic information is stored in an organism's DNA; expression of genes results in the synthesis of functional products, such as rRNA, tRNA and proteins. These products play a role in intra- and extra-cellular biochemical pathways and influence the physiological processes in organisms.

Genomes contain heritable information necessary for continuity of life at all levels: cell, organism and system. This information is stored and passed on to subsequent generations via DNA. Reproduction can occur at the cellular or organismal level; each progeny needs to receive heritable genetic information from its parent(s).

**The cell cycle is tightly regulated**

The cell cycle comprises interphase, nuclear division and cytokinesis. There are two types of nuclear division: mitosis and meiosis. A cell cycle that involves mitosis will give rise to genetically identical cells and this is important for growth, repair and the asexual reproduction of organisms. This cycle is coupled intricately with another important process of the living cell: DNA replication, which occurs during the synthesis phase of interphase. The mitotic cell cycle is tightly regulated at various checkpoints that control the rate of cell division; uncontrolled cell division could result in cancer.

A cell cycle that involves meiosis occurs in the reproductive organs of organisms and is important for sexual reproduction. Meiosis results in gametes having half the amount of genetic material present in somatic cells. The crossing-over of non-sister chromatids and the independent assortment of bivalents in meiosis, together with the random fertilisation of male and female gametes, contribute to genetic variation in populations. Genetic variation is essential for natural selection to occur. Homogeneity of a population can result in the entire population being wiped out by diseases or climatic change.

**Mutation arises from imperfect replication of genetic information; together with other biological processes, such mutations increase genetic variation**

Based on the central dogma, a change in the sequence of the DNA nucleotide, i.e. gene mutation, may affect the amino acid sequence in the polypeptide and hence the phenotype of the organism. Many mutations are detrimental to the individual since they affect the normal functioning of the gene product, e.g. genetic diseases such as sickle cell anaemia. Others are neutral, often because they have no effect on the phenotype, e.g. a change in a DNA triplet which still codes for the same amino acid. Occasionally, mutations may be beneficial. For example, individuals that are heterozygous for a mutated haemoglobin gene that causes sickle cell anaemia have a selective advantage in areas where malaria is common. Besides mutation of genes, chromosomal aberration and changes in chromosome number may also occur. Down syndrome arises due to the presence of an additional copy of chromosome 21.

Mutation, meiosis and sexual reproduction give rise to genetic variation within a population. The expression of genes gives rise to functional products that affect the biochemical reactions and physiological functions of organisms. This demonstrates how the genotype and phenotype of an organism are related. Besides its genotype, the environment also plays a role in determining the phenotype of an organism and this is related to the field of epigenetics. Some examples of environmental factors include the availability of nutrients and changes in temperature.

**The chromosomal basis of inheritance sheds light on the pattern of transmitting genes from parent to offspring**

When Gregor Mendel first started his investigations into inheritance, the concept of genes had not existed yet. He used the term 'traits' in place of genes. By using genetic diagrams, the phenotypic and genotypic ratios of filial generations can be predicted for crosses involving monohybrid or dihybrid inheritance. In line with Mendelian genetics, pedigree diagrams can be used to predict the probability of inheriting genetic diseases such as haemophilia and Huntington's disease.

Non-Mendelian inheritance involves more complex traits. For example, some genes are found on sex chromosomes while others involve multiple alleles. Alleles of some genes exhibit co-dominance or incomplete dominance.

## A. The Structure of Nucleic Acids and Gene Expression

The structure of DNA was proposed by Watson and Crick in 1953. With an understanding of DNA structure, experimental evidence supported the proposal that DNA replicates in a semi-conservative manner. The central dogma states that genetic information is encoded in the DNA and transferred to the mRNA during transcription. In addition to mRNA transcription, tRNA and rRNA are transcribed; tRNA is needed during translation while rRNA is a component of ribosomes. In eukaryotic transcription, pre-mRNA is synthesised and then processed to produce mature mRNA. Subsequently, through translation, the information on the mRNA is used to synthesise polypeptides, which are folded into functional proteins.

| **Learning Outcomes** |
| --- |
| (a) Describe the structure and roles of DNA and RNA (tRNA, rRNA and mRNA) (knowledge of mitochondrial DNA is not required). |
| (b) Describe the process of DNA replication. |
| (c) Describe how the information on DNA is used to synthesise polypeptides in cells. (Description of the processes of transcription, formation of mRNA from pre-mRNA and translation is required.) |

## B. DNA Mutations

Changes to the DNA sequence or amount could have huge physiological impact on organisms. This concept illustrates how DNA mutations could result in sickle cell anaemia and Down syndrome in humans.

| **Learning Outcomes** | |
|---|---|
| (d) | Explain what is meant by the terms *gene mutation* and *chromosomal aberration*. For gene mutation, knowledge of how substitution, addition and deletion could change the amino acid sequence (including frameshift) is required. For chromosomal aberration, knowledge of numerical aberration (including aneuploidy, as in the case of trisomy 21, i.e. Down syndrome) and structural aberration (including translocation, duplication, inversion and deletion) is required. |
| (e) | Explain how gene mutations can result in diseases (including sickle cell anaemia). |

## C. The Cell Cycle

There are two different types of cell cycles: mitotic and meiotic. The mitotic cell cycle is necessary for growth and repair while the meiotic cell cycle is necessary to generate gametes.

Cell cycles are tightly regulated at various checkpoints. The development of cancer is a multi-step process that comprises gene mutations caused by environmental factors, biological agents or hereditary predispositions. These mutations might cause cells to bypass cell cycle checkpoints. Cancer has a much higher incidence in Singapore compared to other diseases and accounts for as much as 30 percent of the deaths in this country. The recorded incidence of cancer is on the rise and this could be due to the accumulation of mutations from one generation to the next, although other reasons have also been proposed: increased exposure to carcinogens and increased detection rates as a result of effective cancer screening programmes.

| Learning Outcomes |
| --- |
| (f) Describe the events that occur during the mitotic cell cycle and the main stages of mitosis (including the behaviour of chromosomes, nuclear envelope, cell surface membrane and centrioles). |
| (g) Explain the significance of the mitotic cell cycle (including growth, repair and asexual reproduction) and the need to regulate it tightly (knowledge that dysregulation of checkpoints of cell division can result in uncontrolled cell division and cancer is required, but details of the mechanism are not required). |
| (h) Identify the causative factors, including genetic, chemical carcinogens, ionising radiation, which may increase the chances of cancerous growth. |
| (i) Describe the development of cancer as a multi-step process that includes accumulation of mutations that affect the cell cycle (details of tumour suppressor genes and proto-oncogenes are not required), angiogenesis and metastasis. |
| (j) Explain the significance of the meiotic cell cycle (reduction division prior to fertilisation and cells not genetically identical) and that meiosis and random fertilisation can lead to variation. (Detailed description of the behaviour of chromosomes during meiosis is not required. Information about the stages and associated behaviour of the nuclear envelope, cell surface membrane and centrioles is not required.) |

**D. Inheritance**

This concept includes both Mendelian and non-Mendelian inheritance. Besides genetics, the environment also plays a role in determining the phenotype of an organism.

| **Learning Outcomes** |
| --- |
| (k) Explain the terms: *locus, allele, dominant, recessive, codominant, incomplete dominance, homozygous, heterozygous, phenotype, genotype* and *sex linkage*.<br><br>(l) Explain how genes are inherited from one generation to the next via the germ cells or gametes.<br><br>(m) Explain, with examples, how the environment may affect the phenotype (including how temperature affects fur colour of Himalayan rabbits).<br><br>(n) Use genetic diagrams to solve problems in dihybrid crosses, including those involving codominance, incomplete dominance, multiple alleles and sex linkage.<br><br>(o) Use genetic diagrams to solve problems involving test crosses. |

## 2.3 CORE IDEA 3: ENERGY AND EQUILIBRIUM

This core idea describes how energy is obtained, transformed and utilised in biological systems.

Students can frame their learning using the following questions:

- How do organisms obtain and use energy for growth and survival?

**Energy is Needed to Drive Biochemical Processes in Organisms**

To maintain life-sustaining processes, organisms require materials and energy from their environment. Nearly all energy that sustains life ultimately comes from the sun. Plants and other photosynthetic organisms make use of sunlight to synthesise carbohydrates from carbon dioxide and water during the process of photosynthesis. Light energy from the sun is converted into chemical energy in the form of carbohydrates. This chemical energy may be used to form plant matter or subsequently released to fuel activities within the plants.

All other organisms depend on autotrophs for energy, either directly, by feeding on autotrophs such as plants; or indirectly, as energy is passed along food chains from one organism to the next. Food provides a source of carbohydrates which are broken down to release energy to phosphorylate ADP to ATP during aerobic respiration. Anaerobic respiration follows a different and less efficient chemical pathway to provide ATP. ATP obtained from respiration is used to drive various essential cellular processes.

In eukaryotes, photosynthesis and respiration occur in membrane-bound organelles. Many steps in photosynthesis and respiration are controlled by enzymes sequestered in these organelles.

**Transformation of Energy between the Environment and Organisms**

Plants and other photosynthetic organisms use sunlight to synthesise carbohydrates from carbon dioxide and water during the process of photosynthesis. The light-dependent (cyclic and non-cyclic photophosphorylation) and light-independent stages of photosynthesis facilitate the conversion of light energy to chemical energy in the form of carbohydrates. Carbohydrates produced from photosynthesis can be assembled into macromolecules or broken down subsequently to fuel activities within the plants. The Calvin cycle ultimately results in the synthesis of sugars in plants.

As heterotrophs consume plant matter, energy from the plants is transferred to them. Chemical processes occur during aerobic respiration whereby carbohydrates are broken down to release energy to phosphorylate ADP to ATP during aerobic respiration. The energy is transferred between interacting molecules through the four stages of aerobic respiration when oxygen is present. In the absence of oxygen, anaerobic respiration occurs with the release of fewer ATP molecules and the formation of either lactate or ethanol depending on the cell type.

| **Learning Outcomes** | |
|---|---|
| (a) | Identify the initial reactants and final products for each of the main stages of respiration under aerobic conditions (glycolysis, link reaction, Krebs cycle and oxidative phosphorylation). (Details of the intermediate molecules and enzymes in each biochemical pathway are not needed.) |
| (b) | State that glycolysis occurs in the cytoplasm and that the link reaction, Krebs cycle and oxidative phosphorylation occur in the mitochondria. |
| (c) | Identify the initial reactants and final products for respiration under anaerobic conditions in yeast and mammalian muscle tissue. (Details of the intermediate molecules and enzymes in each biochemical pathway are not needed.) |
| (d) | State that respiration under aerobic conditions releases more energy than respiration under anaerobic conditions. |
| (e) | State that photosynthesis occurs in chloroplasts. |
| (f) | Identify the initial reactants and final products of the light-dependent and light-independent stages (Details of the intermediate molecules and enzymes are not required.) |
| (g) | Outline briefly that photosynthesis involves conversion of light energy to chemical energy and this energy is stored in the form of carbohydrates. |

## 2.4 CORE IDEA 4: BIOLOGICAL EVOLUTION

This core idea helps students make sense of biology and the biodiversity of life on earth. Three important concepts within evolutionary biology are the:

1. definition of evolution and descent with modification;
2. processes of evolutionary change, natural selection and genetic drift

Students can frame their learning using the following questions:

- Why are there so many similarities among organisms yet so many different plants, animals and microorganisms?

### Natural Selection is the Major Driving Mechanism of Evolution

The essential features of natural selection contribute to the change in the genetic makeup of a population over time. Darwin's theory of natural selection (and, in parallel, Wallace's similar observations and conclusions) states that inheritable variation occurs in individuals in a population.

Due to competition for resources that are often limited, individuals with more favourable variations or phenotypes are more likely to survive and produce more offspring, thus passing on the alleles that code for those traits to subsequent generations. Fitness is a measure of evolutionary success as indicated by the number of surviving offspring left to produce the next generation. It is worth noting that individual organisms do not evolve; rather, it is populations that evolve.

As the environment is always changing, a diverse gene pool is important for the long-term survival of a species. Genetic variation within a population contributes to the diversity of the gene pool. Changes in genetic information may be silent (with no observable phenotypic effects) or result in a new phenotype, which can be favourable, detrimental or neutral to the organism. The interaction of the environment and the phenotype determines the fitness of the phenotype; thus, the environment does not direct the changes in DNA, but acts upon phenotypes that occur through random changes in DNA. These changes can involve alterations in DNA sequences, changes in gene combinations and/or the formation of new gene combinations. Note that there is no perfect genome for organisms.

### Natural Selection and Adaptation

Natural selection occurs only if there is both variation in the genetic information between organisms in a population and variation in the expression of that genetic information, i.e. trait variation leads to differences in performance among individuals. The traits that positively affect survival are more likely to be reproduced and thus are more common in the population.

The interaction of four factors is considered in evolution:

1. The potential for a species to increase in number;
2. The genetic variation of individuals in a species due to mutation and sexual reproduction;

3. The competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce; and
4. The ensuing proliferation of the organisms able to survive and reproduce better in that environment.

Adaptation results from the accumulation of favourable genetic changes through natural selection, since organisms that are anatomically, behaviourally and physiologically well-suited to a specific environment are more likely to survive and reproduce. This differential survival and reproduction of organisms in a population that have an advantageous, heritable trait leads to an increase in the proportion of individuals in future generations that have the favourable trait and to a decrease in the proportion of individuals that do not.

Adaptation also means that the distribution of traits in a population can change when conditions change. Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline (and sometimes the extinction) of some species.

Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the evolution of the species is lost.

| **Learning Outcomes** |
| --- |
| (a) Explain why variation (as a result of mutation, meiosis and sexual reproduction) is important in natural selection.<br><br>(b) Explain, with examples, how environmental factors act as forces of natural selection.<br><br>(c) Explain the role of natural selection in evolution.<br><br>(d) Explain why the population is the smallest unit that can evolve.<br><br>(e) Explain how genetic variation (including harmful recessive alleles) may be preserved in a natural population. |

## 2.5 EXTENSION TOPIC: IMPACT OF CLIMATE CHANGE

Climate change, which is attributed to an increase in the emission of greenhouse gases, has great impact on the human population. By the year 2050, climate change is expected to cause the extinction of approximately at least one quarter of all species on land. In the oceans, species such as corals, which are sensitive to warming temperatures, are also at great risk. Many species have evolved to survive within specific temperature ranges and cannot adapt to the new temperatures. In addition, the survival of a species is threatened when the species it depends on for food cannot adapt. The Intergovernmental Panel on Climate Change (IPCC) has predicted that by 2100, the Earth's surface will rise by up to 6°C on average. The effects of this temperature rise on species and ecosystems will be catastrophic. Currently, the following effects of global warming are evident: the melting of glaciers; the bleaching and dying of coral reefs; extreme storms, droughts, and heat waves; and major shifts in the timing of organisms' biological cycles.

The study of biological processes is important in understanding and taking appropriate action, e.g. the observation that many species are becoming smaller in size can be explained by fundamental ecological and metabolic principles. There are also consequences for both crop plants and protein sources, e.g. fish that are important for human nutrition.

As a small, low-lying city-state with one of the world's most open economies, Singapore is vulnerable to the harmful effects of climate change, such as rising sea levels and the increased frequency of rainfall.

Trends in our local weather records are consistent with the global observations of climate change. The weather has become increasingly hot. Since the 1970s, Singapore has experienced an average warming rate of 0.25°C per decade. The sea level has also risen. Tide gauge data in the Singapore Straits shows that the mean sea level has increased by about 3 mm per year over the last 15 years. More instances of short, intense rainfall have also been recorded within the last few years.

Extreme weather events can lead to changes in rainfall patterns, resulting in more intense rainfall or drier periods. Flood, haze and water management will be of greater importance to Singapore. In addition, an increase in the frequency of extreme weather events may lead to unstable global food prices and disruptions to business supply chains, which will affect our food imports and business activities in Singapore.

Disruption of ecosystems and loss of biodiversity have major impacts on the emergence, transmission, and spread of many human infectious diseases. For example, deforestation reduces the diversity of forest mosquitoes, which are the vectors for dengue. The species that survive and become dominant, for reasons that are not well understood, almost always transmit dengue better than the species that had been most abundant in the intact forests.

Mosquitoes kill more people through the life-threatening diseases they spread than any other predators. Climate change has influenced how mosquito-borne diseases have spread in the world through the effects on the diseases' vectors. Being in a region where two of the main mosquito-borne diseases (dengue and malaria) are endemic, an understanding of the intertwined processes of how vectors respond to climate change and how climate change affects the spread of these diseases will be important to Singapore.

In this topic, the impact of climate change will be studied. The area of concern is the threat of how infectious diseases are changing.

Students can frame their learning using the following questions:

- How can our way of life influence climate change?
- Why is there an urgent need to ameliorate climate change through an understanding and application of the sciences?

| **Learning Outcomes** | |
|---|---|
| (a) | Identify and explain the human activities over the last few centuries that have contributed to climate change through accumulation of greenhouse gases (limited to $CO_2$ and methane), including burning of fossil fuels linked to increasing energy usage, clearing of forests and food choices (increasing consumption of meat). |
| (b) | Explain the effects of climate change as a result of greenhouse gas emissions, including the melting of polar ice caps, rising sea levels, stress on fresh water supplies, heat waves, heavy rains, death of coral reefs, migration of fishes and insects, and release of greenhouse gases in frozen organic matter. |
| (c) | Explain how temperature changes impact insects, including increased temperature leading to increased metabolism and the narrow temperature tolerance of insects. |
| (d) | Outline the life-cycle of *Aedes aegypti* as an example of a typical mosquito vector. |
| (e) | Outline the development of viral dengue disease in humans, including host-pathogen interactions, human susceptibility to the virus, pathogen virulence, transmission and drug resistance. (Knowledge of details of the immune system and mode of viral infection is not required). |
| (f) | Explain how global warming affects the spread of mosquito-borne infectious diseases, including malaria and dengue, beyond the tropics. |

# 3. PEDAGOGY

The starting point for the science curriculum is that every child wants to and can learn. The science curriculum nurtures students as inquirers and taps on their innate curiosity and desire to seek answers to questions or solve problems relating to science. Besides developing a strong conceptual understanding of scientific models and theories, students' curiosity is stimulated and they are encouraged to see the value of science and its applications and connection to their everyday lives.

## 3.1 DEVELOPING CONCEPTUAL UNDERSTANDING

Conceptual understanding is more than factual knowledge which is commonly associated with the memorising of facts and definitions. Conceptual understanding is built by using facts as tools to discern patterns, connections, and deeper, transferable understanding. One approach to develop students' conceptual understanding is through conceptual change that occurs when they are dissatisfied with a prior conception and the available replacement conception is logical, reasonable and/or meaningful.

## 3.2 ENGAGING IN THE PRACTICES OF SCIENCE

Science is not just a body of knowledge, but also a way of knowing and doing. The 'ways of thinking and doing' refer to a discipline's distinctive mode of inquiry and approach to working with the observations and knowledge about the world. Through the Practices of Science, students should appreciate the following:

- **Nature of scientific knowledge:** Students understand the nature of scientific knowledge implicitly through the process of 'doing science'. To complement this, an explicit approach may be used. This approach utilises elements from the history of science or the processes in science to improve students' views of the nature of scientific knowledge.

- **Science as an inquiry:** Scientific inquiry refers to the different approaches by which scientists study and develop an understanding of the natural and physical world around us. Inquiry-based instruction could be used to develop the different aspects of the Practices of Science together with the understanding of science concepts as well as the dispositions and attitudes associated with science. Inquiry-based strategies could include questioning, demonstrations, use of technology, as well as models and modelling.

- **Relating science and society:** Students should appreciate how science and technology are used in daily life. They should apply and experience the potential of science to generate creative solutions to solve a wide range of real-world problems, ranging from those affecting everyday lives to complex problems affecting humanity, while appreciating the values and ethical implications of these applications. Science education needs to equip students with the ability to articulate their ethical stance as they participate in discussions about socio-scientific issues that involve ethical dilemmas, with no single right answers.

### 3.3 PRACTICAL WORK

Science practical work supports the teaching and learning of science through developing the Practices of Science, experimental techniques, practical manipulative skills and conceptual understanding. It also cultivates interest in science and in learning science. In addition, attitudes like objectivity and integrity, which are important in the learning of the discipline of science, are reinforced.

### 3.4 THE SINGAPORE STUDENT LEARNING SPACE (SLS)

The Singapore Student Learning Space (SLS) is an online platform that supports teaching and learning, it

- **enables our students to learn anytime, anywhere**
  As SLS is available to all students and teachers in every school, it can be a key lever to bring about more pervasive and seamless integration of technology in teaching and learning at schools. Students can access SLS through different devices and learn at their own pace.

- **allows our students to take greater ownership of their learning and work collaboratively**
  Students can do self-directed learning by accessing the resources in SLS on their own or complete learning packages assigned by teachers. Quizzes are auto-graded to give immediate feedback to students. These resources complement other teaching and learning resources such as lecture notes, tutorials, physical manipulatives, etc. There are learning tools available on SLS that enable students to curate and organise information, connect with peers and to create works to demonstrate their learning.

- **complements classroom teaching**
  Teachers can use the MOE curriculum-aligned resources in the SLS, curate own resources from the world-wide-web or develop own resources to complement their teaching. In addition, teachers are supported by visualisation tools in SLS to easily monitor students' learning progress and check for understanding.

- **is collectively shaped by schools and owned by all**
  As SLS is accessible by teachers across all Singapore schools, it provides a unique opportunity for teachers to work collectively to co-develop, adapt and share lessons. Teachers can make use of the co-editing and sharing capabilities in SLS to curate and share lesson designs.

Students can access the SLS through https://vle.learning.moe.edu.sg/login.

# 4. ASSESSMENT

Assessment is the process of gathering and analysing evidence about student learning. This information is used to make decisions about students, curricula and programmes. Assessment for Learning (AfL) is assessment conducted constantly during classroom instruction to support teaching and learning. With the feedback about the state of students' learning, teachers then adapt their teaching strategies and pace based on the students' needs. Assessment of Learning (AoL) aims to summarize how much or how well students have achieved at the end of a course of study over an extended period of time. The A-level examination is an example of AoL.

## 4.1 A-Level Examination

Candidates will be assumed to have knowledge and understanding of biology at the O-Level, as a single subject or as part of a balanced science course.

This syllabus is designed to place less emphasis on factual material and greater emphasis on the applications of biology and the impact of recent developments on the needs of contemporary society. This approach has been adopted in recognition of the need for students to develop skills that will be of long term value in an increasingly technological world rather than focusing on large quantities of factual material which may have only short term relevance.

Experimental work is an important component and should underpin the teaching and learning of Biology.

## 4.2 Assessment Objectives

The assessment objectives listed below reflect those parts of the Aims and Practices of Science which will be assessed.

### A Knowledge with Understanding

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

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

The syllabus content defines the factual materials that candidates need to recall and explain. Questions testing the objectives above will often begin with one of the following words: *define, state, name, describe, explain* or *outline* (see Section 4.6 Glossary of Terms).

**B Handling, Applying and Evaluating Information**

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

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

These assessment objectives above cannot be precisely specified in the syllabus content because questions testing such skills are often based on information which is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts that are within the syllabus and apply them in a logical, reasoned or deductive manner to a novel situation. Questions testing these objectives may begin with one of the following words: *discuss, predict, suggest, calculate* or *determine* (see Section 4.6 Glossary of Terms).

## 4.3 SCHEME OF ASSESSMENT

**All candidates are required to enter for Papers 1 and 2.**

| Paper | Type of Paper | Duration | Weighting (%) | Marks |
|---|---|---|---|---|
| 1 | Multiple Choice | 1 h | 33 | 30 |
| 2 | Structured and Free-Response Questions | 2 h | 67 | 60 |

**Paper 1** (1 h, 30 marks)

This paper consists of 30 compulsory multiple choice questions. All questions will be of the direct choice type with 4 options.

**Paper 2** (2 h, 60 marks)

This paper will comprise two sections. Paper 2 will include questions that assess the higher-order skills of analysing, making conclusions and evaluating information and require candidates to integrate knowledge and understanding from different areas of the syllabus.

Section A (45 marks) will consist of a variable number of structured questions, all compulsory, including at least one data-based or comprehension-type question. The data-based question(s) will constitute 10-15 marks of the paper.

Section B (15 marks) will consist of two free-response questions, from which candidates will choose **one**. The quality of scientific argumentation and written communication will be given a percentage of the marks available.

**Weighting of Assessment Objectives**

| Assessment Objective | | Weighting (%) | Assessment Components |
|---|---|---|---|
| A | Knowledge with understanding | 40 | Papers 1 and 2 |
| B | Handling, applying and evaluating information | 60 | Papers 1 and 2 |

### 4.4 ADDITIONAL INFORMATION

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

- The electromagnetic spectrum
- Energy changes (potential energy, activation energy, chemical bond energy)
- Molecules, atoms, ions, electrons
- Acids, bases, pH, buffers
- Isotopes, including radioactive isotopes
- Oxidation and reduction
- Hydrolysis, condensation

**Nomenclature**

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

**Disallowed Subject Combinations**

Candidates may not simultaneously offer Biology at H1 and H2 levels.

**Units and Significant Figures**

Candidates should be aware that misuse of units and/or significant figures, i.e. failure to quote units where necessary, the inclusion of units in quantities defined as ratios or quoting answers to an inappropriate number of significant figures, is liable to be penalised.

*For more information on assessment, please refer to the Singapore Examinations and Assessment Board [https://www.seab.gov.sg/](https://www.seab.gov.sg/).*

## 4.5 MATHEMATICAL REQUIREMENTS

Questions set in the examination may involve the basic processes of mathematics for the calculation and use of decimals, means, ratios and percentages.

Candidates may be required to (i) construct graphs or present data in other suitable graphical forms, and (ii) calculate rates of processes. Candidates should be aware of the problems of drawing conclusions from limited data.

**Calculators**

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

## 4.6 GLOSSARY OF TERMS

It is hoped that the glossary (which is relevant only to science subjects) will prove helpful to candidates as a guide; it is neither exhaustive nor definitive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context.

1. *Analyse* is a context-specific term involving the identification of the constituent parts of a complex situation or result, an assessment of their individual implications and a consideration of how these relate to one another and to scientific knowledge and understanding. Analysis may require further processing of mathematical data to reveal underlying trends and patterns.

2. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.

3. *Classify* requires candidates to group things based on common characteristics.

4. *Comment* is intended as an open-ended instruction, inviting candidates to recall or infer points of interest relevant to the context of the question, taking account of the number of marks available.

5. *Compare* requires candidates to provide both the similarities and differences between things or concepts.

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

7. *Define (the term(s)...)* is intended literally. Only a formal statement or equivalent paraphrase being required.

8. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena.
   In other contexts, describe and give an account of should be interpreted more generally, i.e. the candidate has greater discretion about the nature and the organisation of the material to be included in the answer. Describe and explain may be coupled in a similar way to state and explain.

9. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula, e.g. relative molecular mass.

10. *Discuss* requires candidates to give a critical account of the points involved in the topic.

11. *Draw* is often used in the context of drawing biological specimens. This is an instruction to make a freehand diagram to show the structures observed, as accurately as possible with respect to shape and proportion. Lines delimiting distinct regions should be continuous.

12. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.

13. *Evaluate* is a context-specific term requiring a critical use of information to make a judgement or determination of a particular value or quality (e.g. accuracy). Evaluation of the validity of an experimental procedure, a set of results or a conclusion involves an assessment of the extent to which the procedures, results or conclusions are likely to obtain or represent a 'true' outcome. This will require consideration of the advantages and disadvantages, strengths and weaknesses, and limitations of the underlying approach, as well as other relevant criteria as applicable, and their relative importance.

14. *Explain* may imply reasoning or some reference to theory, depending on the context.

15. *Find* is a general term that may variously be interpreted as calculate, measure, determine etc.

16. *Justify* requires candidates to give reasoning in support of an answer (for example, a decision, conclusion, explanation, or claim), based on a consideration of available evidence, including experimental data, together with relevant scientific knowledge and understanding.

17. *Label* requires candidates to use an appropriate label (and labelling line, where necessary) to accurately show the position of a structure, region or point within a diagram or graph, according to the requirements of the assessment.

18. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified, this should not be exceeded.

19. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.

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

21. *Predict* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an early part of the question.

22. *Recognise* is often used to identify facts, characteristics or concepts that are critical (relevant/ appropriate) to the understanding of a situation, event, process or phenomenon.

23. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, but candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value.
In diagrams, sketch implies that a simple, freehand drawing is acceptable: nevertheless, care should be taken over proportions and the clear exposition of important details.

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

25. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer (e.g. in chemistry, two or more substances may satisfy the given conditions describing an 'unknown'), or to imply that candidates are expected to apply their general knowledge to a 'novel' situation, one that may be formally 'not in the syllabus'.

26. *What is meant by (the term(s)...)* normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.

# 5. RESOURCES AND REFERENCES

Students may find reference to the following books helpful.


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15. Raven, P. H., Johnson, G. B., Mason, K. A., Losos, J. and Singer S. (2013) Biology (Tenth Edition) (McGraw-Hill) ISBN 007338307
16. Reece, J. B., Taylor, M. R., Simon, E. J. and Dickey, J. L. (2013) Campbell Biology: Concepts and Connections (Seventh Edition) (Pearson) ISBN 1292026359
17. Reece J. B., Urry L. A., Cain M. L., Wasserman S. A., Minorsky P. V., Jackson R. B. (2013) Campbell Biology (Tenth Edition) ISBN 9780321775658

18. Russell, P. J., Hertz, P. and McMillan, B. (2013) Biology: The Dynamic Science (International Edition of Third Revised Edition) (Brooks/Cole) ISBN 1133592058

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