Curriculum Standard for Senior High School Biology (2013)

1. **Foreword**

Science is a cultural and social activity in which humans constantly try to understand the laws of nature. Ever since primitive people tried to understand the occurrence of natural phenomena resulted in the invention of apparatus, human beings have begun to understand nature and transform nature. Based on these activities, human beings have explained and justified the causes and laws of the existence and change of things. Through long-term group efforts, this knowledge is gradually accumulated and integrated into a logical, coherent and testable theoretical system.

Any scientific theory and knowledge are inconsistent and must be established under certain time and space conditions. For example, the widely accepted scientific knowledge, whether it is a concept, a theory or a model, is generally recognised by the scientific community after sufficient rigorous evidence and arguments, but with the discovery of new evidence, these theories will be re-established, tested, adjusted, improved, and even replaced. This is the developmental characteristics of scientific knowledge。

Since the twentieth century, the rapid development of scientific knowledge and technology has not only changed the face of science itself, but also deeply influenced people's daily life and their surroundings. Today, many things around us, such as health care medicines, clean drinking water, computers and communication technologies, are all connected with science and technology. Compared with the past, presently we need to analyse and judge the science-related information and arguments in life to make reasonable choices and informed decisions. There are growing professions in the workplace which demand a high level of scientific knowledge and thinking ability to make decisions and solve problems from the incumbents. Internationally, countries are also more active in enhancing their creativity and quality in science and technology research and development to enhance their productivity and competitiveness. Scientific literacy is an essential knowledge for survival in modern world and future, both for the betterment of individuals and society.

Therefore, the core of science education is to cultivate citizens with scientific literacy. This not only lays the foundation for the study of science and technology, but more importantly, enables each citizen to use scientific knowledge principles, methods and scientific thinking to think and make decisions in daily life and society.

Since the second half of the twentieth century, Biology has advanced rapidly and has achieved many breakthrough achievements. For example, the revelation of the structure and functions of DNA molecules, the successful cloning of mammalian somatic cells, and the completion of the human genome project. These major breakthroughs mark the beginning of a new era in bioscience and biotechnology. The biological sciences have an ever-increasing impact on society, economy and human life, and play an increasingly important guiding role in solving population problems, food shortages, resource depletion, environmental degradation, and ecological imbalances. Therefore, in this century, secondary Biology education also assumes a new mission.

In order to adapt to the development of the times, this course strives to reflect the biological classics and core content, but also reflect the new progress of contemporary biological sciences and technology to meet the needs of the times and the needs of social development.

2. Purpose

Biology is an important science subject in high school curriculum. It is a basic course for cultivating students' scientific literacy and promoting students' all-round development. This course is based on the science education of junior high school to further improve students' scientific literacy and focus on the formation and development of students' biological knowledges and concepts, processes, methods and abilities, affective attitudes and values.

The purpose of this course is to:

1. Inspire students to understand the various life phenomena in life and nature, and cultivate curiosity and interest in surrounding entities, thus to beg questions and seek answers;
2. Help students construct and understand the important concepts, principles and models that scientists use to explain life phenomena, and understand the diversity and unity of biological knowledge;
3. Develop the skills of scientific inquiry, rational and critical thinking, creativity, and the ability to solve biological problems independently or cooperatively;
4. Develop students' ability to collect and process scientific information, and effectively articulate and communicate on biologically relevant issues, as well as to make reasonable inferences and decisions;
5. Help students understand the relationship between science, technology and society and the environment, and understand the importance of protecting the environment and sustainable development;

6. Help students understand the nature of science, its strengths and limitations, and the relationship between Biology and other disciplines;
7. Emphasise on the formation of students' positive and learning attitudes, so that students are capable to learn independently and practice lifelong learning; and
8. Establish positive values and scientific attitudes, as well as a sense of responsibility towards nature and society, and be an ethical and responsible citizens.

3. Objectives

The objectives of this course are divided into three dimensions: (1) knowledges and concepts, (2) processes, methods and abilities, and (3) scientific attitudes, affects and values.

(1) Knowledges and concepts

Students should be able to:

1. Understand the concepts, principles, laws, and models of biology;
2. Master the important facts of Biology and basic vocabulary terms;
3. Understand the application and impact of Biology and biotechnology in life, production and social development; and
4. Understand the development and issues of Biology.

(2) Processes, methods and abilities

Students should be able to:

1. Ask appropriate questions and make assumptions;
2. Design and implement an experimental protocol;
3. Collect and analyse materials and data accurately;
4. Make reasonable judgments and conclusions based on the evidence;
5. Exchange ideas on topics related to Biology effectively;
6. Ability to acquire biological information and to analyse, select, apply and share relevant biological information;
7. Conduct scientific inquiry or complete related tasks in a personal or collaborative manner;
8. Apply biological knowledge and concepts to familiar and unfamiliar situations;
9. Apply biological knowledge and principles to make reasonable inferences and appropriate decisions on relevant social issues;
10. Know how to apply the biological knowledge and technology learned to solve problems in life; and
11. Have scientific thinking, critical thinking skills and creativity.

(3) Scientific attitudes, affect and values

Students should be able to:

1. Learn biology, appreciate the mystery and complexity of nature, and respect all living things and the environment willingly;
2. Recognise the urgency of environmental protection, understand individual's responsibility for environmental protection, and be willing to participate in activities to protect the environment;
3. Focus on biological issues related to Biology and reflect on the impact of biotechnology on society, ethics and the environment;
4. Develop good living and hygienic habits and establish a positive and healthy attitude towards life;
5. Develop an attitude of independent learning and continuous learning;
6. Respect objective facts, maintain a skeptical and open attitude, respect different opinions, and dare to express their opinions; and
7. Recognise the limitations of science and not superstitious towards authority.

(4) Period allocation

This senior high school Biology is divided into 5 periods per week for Senior 1; 4 periods per week for Senior 2 and 4 periods per week for Senior 3. Forty minutes is allocated per period and altogether there are 30 weeks for Senior 1 and Senior 2, and 15 weeks for senior 3. The total number of lessons are 330 periods. This allocation includes the time for experiment and activity.

(5) Content

The course content is an important part of the "Curriculum Standard for High School Biology" and a further embodiment of the course objectives. The curriculum standard targets at three dimensions: (1) knowledge and concepts, (2) processes, methods and abilities, and (3) scientific attitudes, affects, and values through five content themes, namely scientific inquiry, structure and function of organisms, Biology and environment, genes and inheritance and evolution and biodiversity.

(1) Scientific inquiry

(1) Identify and raise biologically relevant questions;
(2) Apply existing knowledge, make reasonable assumptions about the answers to the questions, and estimate the verifiability of the hypotheses;
(3) Select and design an appropriate, systematic inquiry plan. This includes how to predict the variables of the experiment, how the results of the inquiry are

affected when both the method and the time change, and finally test the hypothesis;
(4) Experiment with appropriate equipment and methods (examples: select control variables, design control experiments);
(5) Collect and organise evidence and data. Use diagrams, models, etc. to express phenomena and relationships derived from data and explain them with scientific theories;
(6) Use the evidence obtained to support the conclusions of the inquiry;
(7) Know the source of the error, whether the variable can be controlled, the information analysis is accurate, the logic of the discussion and the experimental design, and whether the presupposition is established, and then determine the uncertainty and validity of the scientific conclusion;
(8) Explain or criticise a scientific discourse through experimental evidence and suggest other possible explanations;
(9) Distinguish the scientific consensus that has been recognised and the results of scientific research that are not widely accepted; and
(10) Understand and follow the safety measures that should be taken into account when conducting experiments.

(2) Structure and function of the organism

1. Chemical composition of life

Knowledges and concepts

(1) Link the importance of water and inorganic ions to life;
(2) Explain the relationship between hydrogen bonding and the nature of water;
(3) Describe the composition of four organic molecules, namely saccharides, lipids, proteins, nucleic acids;
(4) Identify the basic structure of each monomer (glucose, fatty acid, glycerol, amino acid, nucleotide);
(5) Describe how bio-macromolecules are formed by condensation of monomers, whereas bio-macromolecules can be decomposed into monomers via hydrolysis;
(6) Analyse the basic structure of cellulose and starch and relate this structure to its function;
(7) Analyse the molecular structure of triglycerides and phospholipids and correlate this structure with its function;
(8) Explain the definitions of the primary, secondary, tertiary, and quaternary structures of proteins and describe the various bonds that maintain the molecular structure;

(9) Analyse the molecular structure of the quaternary protein (such as heme, collagen) and link this structure to its function; and
(10) Distinguish the basic structure of DNA and RNA and relate this structure to its function.

Processes, methods and abilities
(1) Apply appropriately terms related to the chemical composition of life, such as hydrogen bonds, peptide bonds, phospholipids, double helices, condensation reactions, and the like;
(2) Make a three-dimensional model of an organic molecule (saccharide, lipid, protein or nucleic acid);
(3) Design and conduct an experiment to identify the ingredients contained in the tissue (or food); and
(4) Discuss the consequences of the lack of sugars, lipids, proteins and vitamins in living organisms.

Scientific attitudes, affect and values
(1) Identify the materiality of life;
(2) Identify the unity of material composition in the biological world; and
(3) Understand the contribution of scientists and the rigor of scientific knowledge through the scientific history of scientists discovering the structure of biomolecules.

2. Cell structure and function

Knowledges and concepts
(1) Able to recognise the cellular structure exhibited by optical and electron microscopy;
(2) Able to distinguish the main differences between prokaryotic and eukaryotic cell structures;
(3) Able to analyse the similarities and differences between the structure and function of animal and plant cells;
(4) Able to give an example of a cell to show it is the basic unit of life activity structure and function;
(5) Able to understand that the structure and function of cells is achieved by organelles;
(6) Able to describe the correlation between the structure of the organelle and its function;
(7) Able to use the flow mosaic model to explain the nature and function of the cell membrane;

(8) Able to use a flow mosaic model to explain how substances enter and exit cells;
(9) Able to describe the structure and function of the nucleus and cell wall; and
(10) Able to understand that extracellular fluid is the living environment of human cells.

Processes, methods and abilities
(1) Apply terms related to the structure and function of cells, such as: macromolecules, passive transport, active transport, nuclear nuclei, flow mosaic models, etc. appropriately;
(2) Use the microscope correctly.
(3) Conduct Microscope biological specimen slicing and draw a cell structure diagram under an optical microscope;
(4) Make models, such as cell membranes, surface area to volume ratio of different sized materials;
(5) Explore the effect of surface area to volume ratio on diffusion rate;
(6) Explore factors that influence the rate at which a substance penetrates through the selective membrane; and
(7) Explore the relationship between the concentration of extracellular fluid and plasmolysis in plants.

Scientific attitudes, affect and values

(1) Experience the contribution of the development of microscopy technology to cell discovery;
(2) Experience the mystery and complexity of life through the study of cell structure and function; and
(3) Understand the importance of osmosis and active transport to living things;
(4) Assess the impact of cell biology and related technologies on personal life and society. (For example, the knowledge of metabolic processes is related to the choice of individuals in sports, diet, drug applications, etc.)

Conversion of substances and energy in cells
1. Conversion of substances and energy in cells

   Knowledges and concepts
   (1) Understand the properties of the enzyme and its role in metabolism;
   (2) Explain the role of the enzyme by the following concepts:
   Active site, reduced activation energy, specificity of enzyme-substrate complex and enzyme;
   (3) Explain the catalytic mode of the enzyme by inducing fit model;

(4) Describe the factors affecting the rate of enzyme action (substrate concentration, enzyme concentration, temperature, pH, inhibitor);
(5) Illustrate the application of enzymes in life and technology;
(6) Explain why an organism needs energy;
(7) Understand the structure of ATP;
(8) Describe how ATP stores and releases energy;
(9) Link the structure of the chloroplast to its function in photosynthesis;
(10) Understand the dependence of dark reactions on photoreaction;
(11) Understand the chemical changes and energy transfer in photoreaction and dark reactions;
(12) Link the structure of mitochondria to its function in respiration;
(13) Understand the chemical changes and energy transfer in glycolysis, Krebs cycle, electron transfer systems, and oxidative phosphorylation; and
(14) Explain the effects of environmental factors on photosynthesis and respiration.

Processes, methods and abilities
(1) Apply terms related to the conversion of substances and energy in cells, such as: substrate, substrate-enzyme complex, glycolysis, etc. appropriately;
(2) Explain graphically how enzyme reduces the activation energy of the reaction;
(3) Explore factors that affect the rate of enzyme reaction (e.g. temperature, pH); and
(4) Explore the conditions, raw materials and products of photosynthesis, explain the observed phenomena, and present the results of the inquiry in a scientific way.

Scientific attitudes, affect and values

(1) Understand the scientific discovery process and methods from the scientific history data of human exploration photosynthesis, and appreciate the attitude and spirit of scientific inquiry; and
(2) Analyse the role of metabolism in the interaction and interrelationship between biotics and abiotics (e.g. treatment of sewage with microorganisms and enzymes, decomposition of waste, conversion of energy).

2. Cell differentiation

Knowledges and concepts
(1) Understand the definition of stem cells;

(2) describe the various tissues of an organism formed by the division and differentiation of stem cells briefly;
(3) Explain the importance of cell differentiation to multicellular organisms;
(4) Understand that organisms enhance the same specific function (such as gas exchange) through different specialised processes (such as the formation of sputum or lungs); and
(5) Identify the structural and functional relationships of cells, tissues, organs, and systems from examples.

Processes, methods and abilities
1) Apply terms related to cell differentiation, such as embryonic stem cells, adult stem cells, cell differentiation, pluripotency, etc. appropriately;
(2) Use a flow chart to indicate the process of cell differentiation; and
(3) Collect information about stem cells and share relevant information.

Scientific attitudes, affect and values
(1) Discuss the controversy over stem cell research and stem cell therapy.

3. Digestive system
Knowledges and concepts
(1) Understand the importance of digestion to provide nutrients for biological growth and energy production;
(2) Understand the function of the digestive system in digestion and absorption;
(3) Give an example of the adaptation characteristics of the digestive system to digestion and absorption;
(4) Explain the importance of physical digestion and chemical digestion; and
(5) Understand the conversion pathway and importance of sugar, protein and fat in the human body.

Processes, methods and abilities
(1) Apply terms related to the digestive system, such as: villi, peristalsis, constipation, ulcers, etc. appropriately;
(2) Use computer simulation or Bio structural model:
(a) Analyse the relationship between the respiratory system, the circulatory system, and the digestive system; and
(b) Identify the organs of the various systems mentioned above, and explain the relationship between the structure of the human body system and its function; and

(4) Describe the role of cells or genes in the digestive system through models/concept maps/flow charts. (such as the role of various cells forming the stomach wall; how pancreatic cells make and secrete trypsin)

Scientific attitudes, affects and values

(1) Evaluate the importance of technology to our understanding of the human digestive system (internal organs). For example: use an endoscope to observe the digestive tract;

(2) Explain how modern technology contributes to the prevention, diagnosis and treatment of digestive diseases; and

(3) Discuss the importance of good eating habits and lifestyles in maintaining digestive health.

4. The transport of animals and plants

Knowledges and concepts

(1) Understand the importance of the circulatory system for the transport of substances in the human body;

(2) Understand the function of the circulatory system in the transport of substances (gases, nutrients, hormones, metabolic waste);

(3) Give an example of the adaptation characteristics of the human body's red blood cells, blood vessels and heart to material transport;

(4) Explain how the blood moves (the principle of blood pressure formation);

(5) Describe the regulation mechanism of heart rate in the human body (e.g. sinus node is controlled by nerves and hormones);

(6) Describe the formation process of tissue fluid;

(7) Describe the process of material exchange between microvasculature and tissue fluid;

(8) Understand how the tissue fluid flows back into the circulatory system;

(9) Explain the adaptation characteristics of various tissues of vascular plants (such as root hairs, transport tissues, etc.) to material transportation; and

(10) Explain the transport mechanism of substances in vascular plants (transportation of water, transport of organic nutrients).

Processes, methods and abilities

(1) Apply terms related to the transportation of animals and plants, such as sinus node, coronary circulation, hemoglobin, diastolic blood pressure, etc. appropriately;

(2) Design and conduct an experiment that includes predicting how changes in the variables, methods, and time of the experiment affect the results of the

investigation to identify the effects of certain variables on the circulatory system (e.g. the effects of exercise and the effects of rest on heartbeat);
(3) Design and conduct an experiment that includes predicting how changes in the variables, methods, and time of the experiment affect the results of the investigation to identify the effects of certain specific variables on plant transpiration rate;
(4) Discuss and predict what the consequences of tissue fluids are if they fail to return to the circulatory system, based on the knowledge and concepts provided in the course content;
(5) Acquire and share knowledge of the principles or mechanisms of antihypertensive drugs to lower blood pressure through group learning; and
(6) Make a slide specimen of the cross section of the Impatiens stem, and draw and mark the structure diagram of each transport organisation.

Scientific attitudes, affect and values
(1) Evaluate the importance of technology to our understanding of the human circulatory system (internal organs);
(2) Explain how modern technology contributes to the prevention, diagnosis, and treatment of diseases of the circulatory system; and
(3) Discuss the importance of good eating habits and lifestyles in maintaining the health of the circulatory system.

5. Animal and plant coordination and response
    1. Neuromodulation of animals
    Knowledges and concepts
(1) State the function of the nervous system between cells and between systems;
(2) Give an example of the adaptive characteristics of the nervous system to its function;
(3) Explain the adaptation characteristics of the structure of neurons to their functions;
(4) Explain how neurons produce, transmit, and transmit nerve impulses;
(5) Understand the effects of drugs on the transmission of nerve impulses;
(6) Understand the mechanism of reflection (unconditional and conditioned reflex) and its significance to living organisms; and
(7) Take the sensitisation principle of the photoreceptor cells of the eye as an example to understand the mechanism of action of the sensory organs.

Processes, methods and abilities

(1) Apply terms related to neuromodulation of animals, such as axons, myelin, nerve impulses, synapses, acetylcholine, conditioned reflexes, etc. appropriately;
(2) Explore the principle of action of drugs on the nervous system (e.g. caffeine, amphetamines, anesthetics, sedatives, etc.);
(3) Identify the central nervous system, the peripheral nervous system (including the autonomic nervous system), and various parts of the human brain using computer simulations or biological models;
(4) Explain the role of cells in the nervous system through models/concept maps/flow charts; (such as the role of Schwann cells in the transmission of nerve impulses); and
(5) Explain graphically the mechanism of action of the sensory organs (such as the principle of sensitisation of rod cells).

Scientific attitudes, affect and values
(1) Evaluate the effects of drugs (such as sedatives, antidepressants, etc.) that improve the performance of the nervous system on the human body;
(2) Analyse the effects of environmental factors on the nervous system (e.g. the effect of lead on nerve cells; the effect of electromagnetic radiation on brain cells); and
(3) Discuss the importance of proper use of drugs and good lifestyles to maintain neurological health.

2. Endocrine system
Knowledges and concepts
(1) Describe the function of the endocrine system between cells and between systems;
(2) Understand the basic principles of how hormones produce physiological effects (the combination of hormones and receptors, the transmission of information, and the physiological responses of cells). (plants only use auxin as an example);
(3) Compare the differences between the nervous system and the endocrine system; and
(4) Outline the function of the hypothalamus and pituitary gland in regulating hormone levels in the body.

Processes, methods and abilities
(1) Apply terms related to hormone regulation of plants and animals, such as hormones, target cells, thyroid hormones, pituitary etc. appropriately;
(2) Collect data to explain the harm of steroids to human health;

(3) Distinguish the pathological difference between type 1 diabetes and type 2 diabetes; and
(4) Collect data to report the application of phytohormones in agricultural or tissue culture.

Scientific attitudes, affect and values
(1) Discuss the effects of artificial hormone therapy and environmental hormones on the human body; and
(2) Discuss the effects of artificial hormones (such as Beta-Agonist) on animals and humans.

6. Homeostasis and the excretory system
Knowledges and concepts
(1) Describe the internal constant action involves the balance of water, ions, body temperature and pH, and explain the importance of maintaining a constant internal environment to achieve optimal metabolic rate;
(2) Understand the activity of the autonomic visceral organs to maintain a constant internal environment;
(3) Describe how the endocrine system, the excretory system, and the nervous system interact to maintain a constant osmotic pressure;
(4) Explain why the concentration of water molecules must be maintained within a certain range in order for cells to exert optimal physiological functions;
(5) Explain the adaptation characteristics of glomeruli to ultrafiltration and the adaptation characteristics of renal tubules to reabsorption;
(6) Explain why the body temperature must be maintained within a certain range in order for the cells to perform optimal physiological functions;
(7) Describe how the body maintains a constant body temperature;
(8) Describe how the endocrine system, nervous system, and liver interact to maintain constant blood glucose and explain the consequences of glycemic imbalance;
(9) Explain the importance of eliminating waste to maintain metabolism in living organisms; and
(10) Understand the function of the excretory system (e.g. kidney, liver, lung) in excretion.

Processes, methods and abilities
(1) Apply terms related to the internal environment constant (homeostasis) and excretion system, such as: kidney unit, Bowman’s capsule, ultrafiltration, vasopressin, insulin, feedback regulation, and the like appropriately;

(2) Use computer simulation or biological model to analyse the relationship between the endocrine system, excretory system, nervous system and homeostasis;
(3) Do experiment to test the composition and pH of urine; and
(4) Explain how drug affects the homeostasis mechanism to achieve therapeutic effects (e.g. the mechanism of action of antipyretic drugs).

Scientific attitudes, affect and values
(1) Discuss the impact of kidney transplantation (mainly on organ trafficking) on social and ethical issues;
(2) Analyse the effectiveness, reliability and limitations of technology and drug testing through the topic "Use of banned athletes"; and
(3) Analyse the social and economic impacts of treatment equipment and techniques for kidney disease (e.g. dialysis).

7. Health and diseases
Knowledges and concepts
(1) Outline the meaning of health;
(2) Understand the relationship between personal lifestyle and health; (Lifestyles include smoking, alcohol abuse, drug abuse, sexual behaviour, eating habits, exercise, stress, personal hygiene, rest, sleep, etc.);
(3) Explain the relationship between microorganisms and human health;
(4) Outline the etiology, mode of transmission, prevention and treatment of infectious diseases (e.g. AIDS or hepatitis B, influenza, dengue fever);
(5) Understand the consequences of the abuse of antibiotics;
(6) Describe the human body in different ways (specific and non-specific immunity) to prevent pathogens from invading;
(7) Outline the mechanism of action of humoral and cellular immunity;
(8) Explain the importance of primary and secondary immune responses;
(9) Outline the principles, benefits, and risks of artificial immunization; and
(10) Outline the causes, prevention and treatment of noninfectious chronic diseases (cardiovascular diseases, diabetes, cancer and allergies).

Processes, methods and abilities
(1) Apply terms related to health and disease, such as antigens, antibodies, allergic reactions, artificial immunity, etc. appropriately;
(2) Collect information on various types of radiation and its harmfulness to human health, and analyse the reliability of each information source;
(3) Assess the health principles and safety of some health products (including food and wearing) on the market;

(4) Display and promote information about AIDS, cancer or other diseases, and how they are prevented, on campus or in the community;
(5) Conduct a questionnaire survey on campus to explore the relationship between lifestyle (such as eating habits, exercise or sleep) and health indicators; and
(6) Explore the principle of the action of drugs on the nervous system (taking local common drugs as an example).

Scientific attitudes, affects and values
(1) Read articles on Robert Koch to learn about Koch's contributions towards medical development;
(2) Discuss the responsibility of individuals and governments in preventing the spread of disease and the importance of community health (such as the pros and cons of statutory vaccination by the Ministry of Health);
(3) The biological knowledge related to physical defense mechanisms and diseases is constantly evolving; and
(4) Understand the fact that medical technology is still limited (If the cause, spread and treatment of some diseases are still unknown).

2. Living things and the environment

Knowledges and concepts
(1) Understand the concepts of the various organisational levels of ecosystems (species, populations, communities, ecosystems);
(2) Understand the effects of abiotic factors (temperature, sunlight, soil, rainfall, salinity) on living things in habitats;
(3) Describe the interspecies relationships that are common in ecosystems and predict how changes in one population can affect other populations;
(4) Describe the interaction between living things and habitats;
(5) Identify factors in the ecosystem that affect population size changes;
(6) Recognise common population growth patterns;
(7) Identify producers, consumers, and decomposers in the food web and explain the storage and transfer of energy between nutrient layers;
(8) Describe the carbon cycle and nitrogen cycle in ecosystems and illustrate the importance of these effects for sustaining life;
(9) Identify the common ecosystems in Malaysia;
(10) Analyse the importance of ecosystem conservation;
(11) Give an example of how human activities affect the balance of ecosystems;
(12) Give an example of the impact of environmental changes on humans;

(13) Understand the seriousness of environmental damage in our country (for example, the reduction of the area of tropical rain forests and mangroves, the extinction of species, and environmental pollution); and
(14) Explain the importance of biodiversity in maintaining ecosystem balance.

Processes, methods and abilities
(1) Apply biological and environmental related terms such as population, load, population growth, birth rate, mortality, etc. appropriately;
(2) Judge the relationship between the two populations based on the data provided;
(3) Make a model (figure) to represent and explain the food web;
(4) Collect and report information related to our ecosystem;
(5) Discuss the current global and Malaysia's ecological environment problems (such as global warming, damaged forest ecosystems, population growth, etc.).

Scientific attitudes, affect and values
(1) Analyse the population growth, personal consumption of resources, and the impact of technological development on ecosystems;
(2) Discuss the role of individuals and governments in environmental protection and how individuals can contact government-related departments;
(3) discuss the perfect and effectiveness of some environmental protection policies or plans in Malaysia based on research reports; and
(4) Visit Malaysia's ecological conservation areas or participate in environmental protection activities to enhance environmental awareness.

3. Genes and inheritance

1. Cell division

Knowledges and concepts
(1) Outline the need for an organism to form new cells and apoptosis;
(2) Understand the process of mitosis and meiosis (no need to distinguish prophase, metaphase, anaphase and telophase);
(3) Explain that a mother cell forms two daughter cells with the same gene combination through mitosis;
(4) Explain Meiosis is a special type of cell division that reduces the chromosome number by half, creating four haploid cells, each genetically distinct from the parent cell that gave rise to them;
(5) Understand how meiosis causes biological variation;
(6) Understand that cell division is controlled by a group of genes that can cause cell division to be out of control when these genes are mutated;

(7) Explain that uncontrolled mitosis can lead to the formation of tumors and even cancer cells; and

(8) Understand the external factors that can cause genetic mutations may also cause cancer.

Processes, methods and abilities

(1) Apply terms related to cell division, such as haploid, diploid, spindle, somatic cell, association, carcinogen, etc. appropriately;

(2) Compare the differences between mitosis and meiosis; and

(3) draw a flow chart of mitosis and meiosis through collaborative study.

Scientific attitudes, affect and values

(1) Explain how modern technology contributes to cancer testing, diagnosis, treatment, prevention, and control.

2. Reproductive system

Knowledges and concepts

(1) Understand that the role of reproduction is to provide for the continued existence of a species;

(2) Understand the importance of asexual reproduction and sexual reproduction in the continuation of species;

(3) Explain the function of the reproductive system in the following roles: germ cell formation, fertilization, fetal development, childbirth, and feeding;

(4) Understand the relationship between estrogen and physiological changes in individuals during the menstrual cycle;

(5) Understand that the menstrual cycle is maintained by a variety of hormone interactions;

(6) Understand the principles and reliability of various methods of contraception (condoms, contraceptives, ligation);

(7) Understand the basic principles and applications of artificial conception; and

(8) Explain the mechanism of sexual reproduction of flower plants.

Processes, methods and abilities

(1) Apply terms related to the reproductive system, such as: ovulation, menstrual cycle, implantation, embryo, fetus, etc. appropriately;

(2) Design experiments (i.e. no actual practice) theoretically to explore the relationship between sexual reproduction and asexual reproduction and genetic variation. Students must reasonably explain the selection and setting of species, equipment, and experimental conditions; and

(3) Discuss other contraceptive methods and their reliability.

Scientific attitudes, affect and values

(1) Evaluate the implications of artificial conception techniques in society and ethics;
(2) Discuss the importance of parental rearing and the benefits of breastfeeding;
(3) Discuss the harmful effects of pregnant women's drinking and smoking habits on fetal development; and
(4) Discuss the acceptance of early pregnancy and induced abortion in different cultures, then discuss their physiological and psychological effects.

3. The material basis of heredity

Knowledges and concepts

(1) Know that the genetic information of all living things is carried by DNA;
(2) A gene is a fragment of a DNA molecule that forms a chromosome with a protein;
(3) It is known that DNA is formed by condensation of four nucleotides;
(4) Understand the chemical and structural properties of DNA (i.e. double helix, sugar/phosphorus skeleton, base pairing) and use this DNA model to:
i. Demonstrate how base sequencing forms codons to interpret the ordering of amino acids in the polypeptide chain;
ii. Explain the basic processes of gene transcription and translation, and how these processes contribute to gene expression;
iii. Describe the basic process of DNA replication and how genetic codes are passed and retained through this process;
(5) Know that DNA replication is tightly controlled and highly accurate, spontaneous replication errors (formation changes) still occur. Some environmental factors (such as some radiation and chemicals) can also cause genetic mutations;
(6) Interpret Changes in DNA base sequences do not necessarily lead to changes in the traits of the organism. Only mutations in the genes (new alleles) may cause changes in traits; and
(7) Understand that only when a gene mutation occurs in a germ cell will it be passed on to the next generation. If the gene mutation occurs in a somatic cell, it will only be passed on to the daughter cell.

Processes, methods and abilities

(1) Apply terms related to the material basis of heredity, such as genes, helicases, tRNAs, codons, transcriptions, etc. appropriately;
(2) Collect information and develop flow charts to show how changes in DNA sequencing lead to changes in cellular activity;

(3) Perform DNA extraction experiments using appropriate instruments and methods. Analyse the experimental results and judge the quality of the extracted DNA, the size of the DNA molecules, etc.;
(4) Make a model of DNA;
(5) Search for information on the source of mutagens and their impact on human health; and
(6) Collect data to illustrate the effects of a particular genetic mutation on human health.

Scientific attitudes, affect and values

(1) Review information related to genetic modification to form ideas for the application of this technology and its impact strictly;
(2) Collect the latest information on genetics and technology, knowing that science and technology are constantly evolving;
(3) Recognise the contributions and limitations of data obtained by the Human Genome Project; and
(4) Understand the nature of scientific development from the discovery process of DNA (such as pneumococcal transformation experiments)

4. Genes and Mendel's genetic laws

Knowledges and concepts

(1) The interpretation of genetic information is transmitted from parents to offspring through genes on the DNA. These genes contain information about protein synthesis, allowing offspring to exhibit multiple genetic traits;
(2) Explain the concepts proposed in Mendel's law: genotype, phenotype, dominant and recessive;
(3) Explain the genetic laws of biological characteristics using the concepts of DNA, genes, chromosomes, alleles, mitosis and meiosis;
(4) Identify the genetic laws of different organisms through observable genetic phenomena (dominant inheritance, recessive inheritance, codominant inheritance, sexual inheritance, polygenic inheritance, complex allele inheritance); and
(5) Outline how environmental factors affect an individual's genotype and phenotype.

Processes, methods and abilities

(1) Apply terms related to genetic and genetic laws, such as: alleles, genotypes, phenotypes, dominant, recessive, parental, offspring, etc. appropriately;
(2) Calculate the genotype and phenotype probability of single and double trait hybridisation and associated genetic progeny with different genetic maps (such as Punnett square method);

(3) Use the results of the test to identify the genotype of the parent; and
(4) Use pedigree maps to analyse the genetic pattern of a trait in a family.

Scientific attitudes, affect and values

(1) Read an article about Mendel's contribution to research genetics and experience the scientific attitude and spirit of being a scientist; and
(2) Understand that scientific theories are constantly being revised and developed through the genetic laws of Mendel and Morgan.

5. Applied genetics

Knowledges and concepts

(1) Overview the development and principles of DNA recombination technology and protein engineering, polymerase chain reaction (PCR);
(2) Describe the application of some cell ultra-microscopic structures in biotechnology (such as plasmids, restriction enzymes, recombinant DNA, and genetic engineering vectors);
(3) Understand enzymes as important tools for biotechnology to:
i. Describe the use of restriction endonucleases and DNA ligases in recombinant DNA technology; and
ii. Describe the application of polymerase chaining in the doubling of DNA fragments and DNA sequencing.

Processes, methods and abilities

(1) Apply terms related to applied genetics, such as genetic engineering, DNA recombination techniques, restriction enzymes, genetic modification, etc. appropriately;
(2) Use a chart or video to explain the method of reverse transcription, which can identify the DNA base sequencing of a protein's gene; and
(3) Identify reliable sources of information, collect, analyse and present applications of biotechnology in the medical and pharmaceutical fields. The report should provide details of the methods and processes, identify the organisms or tissues involved, describe the products of each biotechnological process, and evaluate the efficiency of the process, and discuss the advantages and disadvantages of the product or process.

Scientific attitudes, affect and values

(1) Discuss the broad application of bioengineering and its implications for society, ethics, economics and the environment (e.g. issues related to animal cloning and genetically modified foods);

(2) Understand that scientific knowledge can promote the development of new technologies (such as the knowledge of enzyme traits that prompted the invention of the chain reaction of polymerases);
(3) Know that social needs can promote the advancement of technology;
(e.g. production of genetically modified crops to prevent food shortages, recombinant DNA technology and DNA fingerprinting); and
(4) Read articles on the contributions of scientists (such as Morris Kary Mullis, Jeffrey Alec Jeffreys, Boyer Herbert Boyer, and Cohen Stanley N. Cohen) towards the development of genetic engineering.

4. Evolution and biodiversity
    1. Biodiversity

        Knowledges and concepts
        (1) Explain what are biodiversity and its importance;
        (2) Understand the hierarchical classification method. Organise organisms at different levels (Kingdom, Phylum, Class, Order, Family, Genus, Species). "species" is the most basic classification unit;
        (3) Based on structural and physiological characteristics, various types of organisms are classified according to the six-kingdom system (describe the structural and physiological common and different characteristics of each boundary organism);
        (4) Describe the structural characteristics of virus;
        (5) Understand that a virus is different from a cell because it cannot perform any metabolic effects independently;
        (6) Understand the basics of viral replication and explain how the virus harms the health and life of the host;
        (7) Explain some of the key changes in the structure and physiological functions of organisms during evolution (e.g. evolution from prokaryotes to eukaryotes);
        (8) Know that the scientific name is a combination of the generic name and the species name in the hierarchical classification method;
        (9) Understand the advantages and limitations of various classification systems and why some biological classifications change over time; and
        (10) Identify measures to protect biodiversity.

        Processes, methods and abilities
        (1) Apply terms related to biodiversity, such as species diversity, protists, bacteria, fungi, binominal nomenclature, etc. appropriately;
        (2) Design and use a dichotomous key for taxonomy and identification;

(3) Produce classification charts based on the representative characteristics of living organisms;
(4) Collect organisms from ponds, grasslands or other ecosystems through appropriate sampling methods and classifying the collected organisms according to the basic principles of taxonomy;
(5) Carry out microbial culture using the correct aseptic method;
(6) Explore the effects of antibiotics (or other disinfectants) on the growth of different strains; and
(7) Explore and analyse the conditions required for microbial growth (e.g. optimum temperature).

Scientific attitudes, affect and values
(1) Experience the richness of biodiversity on Earth (such as visiting campuses, botanical gardens, zoos, etc.);
(2) Focus on endangered plants and animals;
(3) Analyse the crises and benefits of human activities for biodiversity;
(4) Analyse the possible impacts of climate change on biodiversity;
(5) Discuss the role of individuals and governments in conservation of species and criticise the integrity and effectiveness of our government's conservation policies; and
(6) Assess the positive and negative effects of microorganisms on the environment.

2. Evolution
Knowledges and concepts
(1) Recognise that genetic variation is the basis for the diversity within the population and the formation of new species;
(2) Induct the core concepts of natural selection (genetic variation, over-reproduction, survival competition, survival of the fittest);
(3) Explain how natural selection determines the direction of biological evolution (in a particular environment, individuals with specific variations are more likely to survive, multiply, and pass these mutations to offspring);
(4) Understand that natural selection occurs at the individual level, while evolution occurs at the level of the population;
(5) Know that the reproductive segregation of populations caused by geographical isolation can lead to the formation of new species;
(6) Give examples of genetic variation and environmental factors that contribute to evolution and biodiversity;

(7) Give examples of evidence in paleontology, comparative anatomy, embryology, molecular biology, etc., and how to support the theory of evolution; and
(8) Explain how human activities influence the direction of evolution and biodiversity.

Processes, methods and abilities
(1) Apply evolution-related terms such as natural selection, isolation, and speciation appropriately;
(2) Refer to the contributions towards the modern interpretation of chemistry obtained from research, analysis and reporting scientists (such as Darwin, Lamarck, Wallace, etc.); and
(3) Explore the process of natural selection and artificial selection (such as drug-resistant microorganisms, selective breeding, etc.) through case studies or computer simulations.

Scientific attitudes, affect and values
(1) Discuss the morality of humans in biological breeding; and
(2) Assess the impact of environmental changes on natural selection and species survival.

5. Implementation recommendations

1. Teaching approach

The "Curriculum Standard for Senior High School Biology" aims to improve students' scientific literacy, advocate inquiry-based learning, and care about the relationship between Biology and life as well as society. On the basis of the standard of this course, teachers should continuously reform and improve teaching methods in light of the actual needs of the schools and students, and create contexts for inquiry-based teaching in order to enable learning from knowledge, skills, abilities, methods, emotions, attitudes and values thus to lay the foundation for Students' lifelong learning and further development.

Teaching-led principles:

1. To practice the purpose of the course and implement the course objectives

The purpose and objectives of this curriculum standard are to be embodied and implemented through effective teaching methods and approaches. Teachers must study the "Curriculum Standard for Senior High School Biology" carefully and understand the course objectives, course content and requirements totally. In teaching design, teachers must consider the implementation of the curriculum objectives impartially. The objectives of this curriculum cover three dimensions:

knowledge concept, skills and attitudes. In addition to the acquisition of knowledge, teachers should pay more attention to the requirements of ability and emotional attitudes and values.

2. To focus on conceptual learning

The concept of Biology is the reflection of biological phenomena, essential features or common attributes through abstraction and generalisation. For example, by abstracting, generalising, and extracting the essential attributes and common features of animals (such as elephants, tigers, cows, and sheep) that have characteristics such as viviparous, breast-feeding, thoracic diaphragm, and have hair and fur on the body. The concept of mammals is formed.

The biological concept is an important part of the knowledge of Biology as a subject in the middle high school. It is an accurate and essential exposition of the structure, physiology and even all life phenomena, principles and laws of living things.

Mastering the concept of Biology is a necessary prerequisite for students to learn Biology, including the understanding of life phenomena and their activities, thus to solve problems and even create. Therefore, the mastery and application of concepts is the core issue of the Biology teaching process.

The term ‘concept’ is abstract and is narrated in language and may be difficult for students to understand. The acquisition of concepts depends on practical materials and experience. If the study lacks certain practical materials or experience, it is easy for the students to define the definition without understanding and grasping its true meaning. Teachers can teach concepts by providing students with opportunities to directly observe specific things, or by reminding students to use existing practical experience to enhance the intuitiveness of concept teaching and promote the development of students’ thinking process from individual phenomena to general laws. For example, the teaching of “nastic movement” can first be the demonstration of the potted plant mimosa, followed by letting the students to personally touch and observe the reaction status of the mimosa leaf. After such personally experience as an experiment, teachers can proceed to guide the students to summarise and define the concept, which will enable the students to conceptually understand the term ‘concept’.

In teaching, teachers should guide students to compare and classify some related concepts, identify the internal relationship between concepts, find out the essential differences, and make the concepts clear and systematic in a timely manner. There are many ways to compare, and it can be flexibly selected based on the content of the teaching. Tables and graphic methods (including concept maps) are often used in daily teaching practices.

3. To emphasise on cultivating students’ abilities and scientific attitudes

The purpose of this curriculum standard is to cultivate citizens with scientific literacy. In addition to letting students master the core knowledge of Biology, they should also be taught to pay attention to the cultivation of their comprehensive ability thus to solve various problems in the learning process, as well as to pay attention to the cultivation of their scientific thinking, and the development of attitudes, affect and values. The teaching practices should likewise focus on the development of students' interest in learning, scientific attitude and scientific spirit.

4. To strengthen experimental teaching

Biology is an experiment-based subject. Strengthening experimental teaching is an important component in quest of quality in biological teaching. As such, students can complete the experiments hands-on. The experiments can actually train students' experimental operation skills and improve their experimental inquiry ability.

Schools should gradually put laboratory and equipment in place. While teaching, teachers should also create conditions and use a variety of feasible solutions to undergo biological experiments.

Moreover, the experimental design should be diversified. For example, a relatively standardised experimental instrument to be used in experiment design, or a low-cost experiment to be designed; a biomaterial design experiment can be recommended, or a simulated experiment to be scheduled; or some exploratory and open experiments can be included. As a whole, students should be encouraged to participate in the design of experiments. The experiments can be conducted concurrently with classroom teaching, or to be carried out separately.

Attention should be paid to the development of students' scientific attitudes and skills in the experimental activities. The safe use of experimental instruments and experimental drugs is the basic skill of biological experiments. In experimental teaching, it is necessary to strengthen safety awareness and environmental awareness, and pay attention to the proper disposal of experimental waste.

Pedagogical approach:

The study and teaching of Biology can be summarised into three common and related teaching orientations:

1. Direct teaching

Direct teaching is a teaching orientation in which teachers teach knowledge or demonstrate. This pedagogy consists of three main methods: to explain the content in a structured manner; to provide sufficient guidance for students; and to assess students' understanding through questions, homework or quizzes. Direct

teaching can effectively impart certain biological knowledge, such as the chemical composition of life, the structure of cells, the classification systems and experimental safety.

2. Inquiry-based teaching

Inquiry-based teaching encourages students to actively participate in the search for information. This teaching orientation has a major impact on the operation of the classroom. This pedagogy makes students to actively participate in the process of observing, classifying, speculating, formulating and validating hypotheses, collecting and analysing data, and eventually making conclusions. This Biology course emphasises such teaching orientation. Teachers should appropriately introduce scientific inquiry activities in secondary school study and teaching.

3. Collaborative teaching

Collaborative teaching is based on the learning community where teachers and students learn, share and develop knowledge. This pedagogy emphasises the important role of dialogue between students and between teachers and students. The process of building knowledge together is diverse, such as raising open-ended questions, giving contradictory views and encouraging students to respond, engaging students in discussions and debates, and setting up group work. The focus of the course, such as science, technology, social and environmental connections, and the nature and history of biology are well suited to be learned in a collaborative way. This approach allows students and teachers to bring different experiences and perspectives into the process of constructing knowledge, making learning more effective.

In the decision of learning and teaching orientations and strategies, teachers should engage the learning objectives of the classroom as the basis, flexibly adopt a variety of learning and teaching strategies, and meet the different needs and learning styles of students. In addition, the design should encourage students to achieve multiple learning goals in the same learning process. The table below lists some of the learning and teaching activities commonly used in Biology classes:

Learning and teaching activities commonly used in biology classrooms

Direct teaching	interactive teaching	personal study	Inquiry-based	Collaborative learning
•Explanation •Demonstration •Video playing	• Teacher initiates questions • Class or group	• Make a concept map • Learn from reading • Collect	• Problem relief activities • Scientific inquiry • Experimental	• Forum • Co-play • Debate • Project learning

	discussion • Visit • Use of information technology and multimedia materials	Data collection • Write a learning log / notes	activities • Simulation and model	

Teachers should adopt appropriate learning and teaching orientations to achieve the learning objectives and promote students' active learning. Teachers must carefully arrange learning and teaching activities, such as questions initiation, reading, group discussions, panel discussions, production models, demonstrations, experimental activities, outdoor inspections, inquiry-based activities, oral reports, homework, data search, and role-playing, in order to provide students with comprehensible learning.

2. Evaluation suggestions

1. Evaluation purpose

Evaluation is an indispensable part of the teaching process. Through teaching evaluation, teachers can get feedback on their teaching. It is an important method for teachers to understand the teaching process and regulate teaching activities to ensure that the teaching activities can achieve the set curriculum objectives. The main purpose of the evaluation is to comprehensively understand the process and results of the students' learning, to diagnose whether the students have incorrect concept and learning difficulties, to identify possible defects in teaching and to provide a basis for refining the teaching design.

2. Evaluation content

In the teaching of Biology, the design of evaluation should be based on the "Curriculum Standard for Senior High School Biology", and the content of the evaluation should be responsive to the course objectives. Teaching evaluation should be accompanied by teaching activities, and its content should be consistent with the teaching objectives, covering all aspects of the course objectives. A comprehensive evaluation of students' knowledge, methods and abilities, as well as affect and values must be in place. It is necessary to pay attention to the results of student learning, as well as the changes and development of students in the learning process.

3. Evaluation method

In the implementation of the evaluation, the appropriateness of the evaluation methods and tools is the key to determining the success or failure of the evaluation. Therefore, in the evaluation process, how to choose appropriate and effective methods and develop excellent evaluation tools is a point that Biology teachers must prudently consider. Teachers should use a variety of evaluation methods throughout the teaching process to assess the level of achievement of students in different learning objectives. It is necessary to adapt a variety of evaluation methods that match the evaluation content while giving equal attention to formative evaluation and summative evaluation.

Formative evaluation

Formative evaluation mainly refers to the measurement of students' learning process and results in order to improve and refine teaching activities during the teaching process. Formative evaluation focuses on the assessment of the learning process and on the use of measurement results to improve teaching, so that teaching is refined in the process of continuous evaluation, feedback, correction or improvement, rather than stressing the assessment of students' achievements. Since formative evaluation is the main purpose of obtaining feedback and improving teaching, the number of such tests is relatively frequent. Generally, after the initial teaching of any one unit, new concepts and new skills teaching are completed, the scale of the scope of each test is small.

Formative evaluation assesses modalities such as the performance of students participating in experiments and co-curricular practice activities, the completion of assignments in general, classroom questions raised, discussions and collaborative learning. Emphasis is placed on evaluating students' performance in the learning process, their usual learning attitudes, learning ability and interest in learning. It is intended to promote students' active participation in the learning process and to form correct emotional attitudes and values.

Summative evaluation

Summative evaluation generally refers to the assessment of student learning outcomes after the end of a course or a teaching phase. The main purpose of this type of evaluation is to assess the student's academic performance, determine the extent to which the student achieves the learning objectives, and determine the basis for the student's learning in the follow-up tutorial and the development of new learning objectives. The generalisation level of summative evaluation is generally high, the scope of content included in the examination or test is comparatively broad, and the number of evaluations is restricted, usually two or three times a semester or within one academic year. The mid-term exams, final exams, and graduation exams in the school are all such evaluations.

Summative evaluation engages paper-based test on basic knowledge and non-paper-based test on examination ability, such as experimental skill operation examination, specimen model production, practical activity results, inquiry-based report, investigation report, etc. Different examination contents and requirements will be scheduled for each semester.

Each assessment should adapt appropriate evaluation method in accordance with different teaching contents and the purpose of the evaluation. The available evaluation methods mainly include:

A Short Guide to Writing Effective Test Questions

Don't overemphasise	Emphasise
Less important content	core content
Scattered knowledge	Knowledge of good structure
Simple scientific fact	Practical concepts and principles
Exam contents that require memorisation	Understanding and reasoning skills in biology

(2) Experimental examination

Teachers can use appropriate guidelines to examine students' understanding and application of scientific concepts and principles, ability to design experiments, experimental techniques, ability to process and interpret data obtained, ability to communicate and communicate, spirit of cooperation, spirit of innovation, and safety consciousness, etc. The experimental examination evaluates the performance and results of the students during the experiment (such as the experimental report).

(3) Learning observation

When students are undergoing learning activities, teachers can observe their interest and motivation, way to solve problems, learning attitudes (such as initiative, cooperation, creativity, etc.), and interaction with others. Through a long-term, systematic observation of students' performance in daily learning and recording, a more comprehensive evaluation of students' learning can be obtained.

(4) Oral question

Through asking questions orally, teachers can understand how students think in certain situations. Students' responses can reflect their strengths, weaknesses, fallacies, understanding, attitudes and abilities. Teachers should use different types of questions to stimulate students' thinking, such as asking students to provide facts, set questions, find evidence, and answer open-ended questions that promote higher order thinking.

(5) Project presentation

The project presentation provides an opportunity for students to apply what they have learned. Teachers can use appropriate evaluation methods to evaluate students' creativity, communication and presentation skills, problem-solving skills, and ability to collect and process data. The results of the evaluation should be presented in both qualitative and quantitative methods. Quantitative evaluation can be presented via the grading system, percentage, etc.; qualitative evaluation can be forwarded in the form of comments, activity records filling, etc. More attention should be paid to what students have mastered, what progress they have gained, and what capabilities they have, so that the evaluation are helpful in building students' self-confidence in learning Biology, improving students' interest in learning Biology, and promoting students' development in learning Biology.

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