COMPULSORY PART

I. Cells and Molecules of Life

Overview

Cells and biomolecules are fundamental units of life. Organisms are built up of these fundamental units which function as an integrated whole. The study of the structure and function of cells will lay the foundation for students to understand and relate cellular processes to the essential life processes of organisms. The study of the discovery of cells will enable students to appreciate the contribution of technology to the advancement of science and the dynamic nature of biological knowledge.

Scientific Inquiry

This should enable students to:

- ask relevant questions, identify problems and formulate hypotheses for investigations related to cells and molecules of life;
- plan and conduct scientific investigations in the area of cellular structures and functions;
- use appropriate instruments and proper techniques for carrying out practical work (e.g. food tests, preparation of temporary mounts and microscopic examination);
- make careful observations and accurate records (e.g. examine prepared slides or temporary mounts of tissues and make biological drawings); and
- identify and explain the importance of control variables in scientific investigations (e.g. the study of enzymatic activities, osmosis, photosynthesis and respiration).

STSE Connections

This should enable students to:

- be aware of the applications of biological knowledge of cells and molecules of life in society;
- appreciate the role of science and technology in understanding the molecular basis of life; and
- recognise that the development of microscopic technology, computing technology and image analysing technology may lead to the advancement of biological knowledge.

This should enable students to:

- be aware of the dynamic nature of biological knowledge (e.g. the understanding of cell membrane, sub-cellular organelles and cellular processes);
- recognise the contributions of various people (e.g. Robert Hooke, Theodor Schwann, Melvin Calvin and Sir Hans Krebs) to developments in biology; and
- be aware that biological knowledge and theories are developed through observations, hypotheses, experimentations and analyses (e.g. fluid mosaic model of cell membrane structure).

Students should learn	Students should be able to
a. Molecules of life	
Water and inorganic ions (e.g. nitrogen, magnesium, calcium and iron) Biomolecules: carbohydrates, lipids, proteins and nucleic acids • Building blocks • Functions	• Relate the significance of water, inorganic ions and biomolecules to life.
b. Cellular organisation	
Discovery of cells Cell membrane • Properties and functions Sub-cellular structures and their functions • Nucleus and chromosomes, endoplasmic reticulum, mitochondrion, chloroplast, cell wall and vacuole Prokaryotic cells (e.g. bacterial cells) and eukaryotic cells	• Appreciate the contribution of the technological development of the microscope to the discovery of cells. • Prepare temporary mounts of specimens for examination, and make observations and drawings under a light microscope. • Use the fluid mosaic model to explain the properties and functions of cell membrane. • Appreciate the uses and limitations of scientific models. • Compare the cellular organisation of animal and plant cells. • Identify cell organelles as seen under light and electron microscopes. • Compare the sub-cellular organisation of prokaryotic and eukaryotic cells.
c. Movement of substances across membrane	
Diffusion, osmosis and active transport Occurrence of phagocytosis in cells	• Account for the movement of substances across membrane using the concepts of diffusion, osmosis and active transport. • Apply the concept of osmosis to explain plasmolysis and haemolysis.
d. Cell cycle and division	
Stages of cell cycle • Cell growth, nuclear division and cytoplasmic division	• Understand the importance of cell division in growth and reproduction. • Recognise the various stages of cell cycle.

Students should learn	Students should be able to
Nuclear division • Mitosis • Meiosis	• Outline and compare the processes of mitosis and meiosis.
e. Cellular energetics	
Metabolism: catabolism and anabolism • Occurrence of catabolic and anabolic processes in cells	• Distinguish between catabolic and anabolic processes. • Recognise the properties of enzyme and its roles in metabolism.
Enzymes and enzymatic reactions • Properties and roles of enzyme • Active site and specificity • Factors (temperature, pH and inhibitors) affecting the rate of enzymatic reactions • Application of enzyme in everyday life	• Explain enzyme specificity in terms of active site. • Explain the effects of factors on the rate of enzymatic reactions.
Photosynthesis • Site of photosynthesis – Leaves and chloroplasts • Requirements for photosynthesis – light, carbon dioxide, water and chlorophyll • Photochemical reactions – light absorption – photolysis of water for the generation of NADPH – generation of ATP • Carbon fixation: Calvin cycle – Carbon dioxide fixation and formation of 3-C compound – Reduction of 3-C compound leading to the formation of glucose – Regeneration of carbon dioxide acceptor • Conversions of photosynthetic products into other biomolecules • Factors (light intensity and carbon dioxide concentration) affecting the rate of photosynthesis	• Understand the significance of photosynthesis. • Relate the structures of leaves and chloroplasts to their functions in photosynthesis. • Outline the major steps of photochemical reactions and carbon fixation. • Understand the dependence of carbon fixation to the photochemical reaction. • Explain the effects of environmental factors on the rate of photosynthesis.

Students should learn	Students should be able to
Respiration • Sites of respiration – Cytoplasm and mitochondrion • Glycolysis – Breakdown of glucose to 3-C compound (triose phosphate) – Oxidation of triose phosphate to pyruvate – Production of NADH and ATP • Aerobic pathway – Conversion of pyruvate to acetyl-CoA – Outline of Krebs cycle ▪ Combination of acetyl-CoA with a 4-C compound to form a 6-C compound ▪ Regeneration of 4-C compound with the release of carbon dioxide ▪ Production of NADH, FADH and ATP – Oxidative phosphorylation ▪ Regeneration of NAD and FAD ▪ Formation of ATP • Anaerobic pathway – Formation of lactic acid in muscle cell – Formation of ethanol and carbon dioxide in yeast • Industrial applications of anaerobic respiration	• Understand the significance of respiration. • State the role of ATP in energy transfer. • Outline the major steps of glycolysis, aerobic and anaerobic pathways. • Be aware of the occurrence of anaerobic respiration during exercise. • Distinguish between aerobic and anaerobic respiration. • Compare the processes of respiration and photosynthesis. • Be aware of the interconversions of biomolecules through biochemical pathways.

Suggested Learning and Teaching Activities

a. Molecules of life

- Discuss whether life can exist without water, and the possible benefits of drinking mineral water or isotonic drinks.
- Perform common biochemical tests (e.g. Benedict's test, iodine test, grease spot test, and different types of test papers) to identify the presence of biomolecules in living tissues.

b. Cellular organisation

- Read articles about the discovery of cells.
- Conduct a project to explore the contribution of the development of the microscope to the understanding of cells.
- Discuss the variations of the number of mitochondria in different tissues and cell types.
- Prepare temporary mounts of animal and plant tissues for examination under a light microscope.
- Examine electron micrographs or live cell images of prokaryotic, eukaryotic cells and sub-cellular structures.
- Construct a model to represent the structure of cell membrane (e.g. using tank and ping-pong balls).

c. Movement of substances across membrane

- Perform practical work to study osmosis at cellular, tissue or organ levels.
- Examine live cell images of the processes involved in the movement of substances across membrane.

d. Cell cycle and division

- Observe and identify the different stages of mitosis and meiosis, using prepared slides, photomicrographs or live cell images.

e. Cellular energetics

- Perform practical work to demonstrate the breaking down or building up action of enzymes; and to identify the photosynthetic products.
- Design and perform investigations to study the effects of temperature, pH or inhibitors on the activities of enzymes; to find out some commercial applications of enzymes (e.g. bioactive washing powder and meat tenderiser); to study the effects of environmental factors (e.g. light intensity and carbon dioxide concentration) on the rate of photosynthesis; and to study aerobic and anaerobic respiration in organisms.
- Examine the morphology and the internal structure of leaves, and the photomicrographs or live cell images of chloroplasts and mitochondria.
- Search for information to compare the photosynthetic rates and productivities in different climatic areas; and to understand scientists' work related to photosynthesis and cellular respiration.
- Conduct a project on how a greenhouse works in enhancing plant growth.
- Discuss the application of anaerobic respiration in the food industry.
- Interpret, analyse and evaluate data relating to investigations on photosynthesis and respiration.
- Use animations to study the processes of photosynthesis and respiration.

COMPULSORY PART

II. Genetics and Evolution

Overview

Through the study of basic genetics, students will acquire knowledge and develop an understanding of concepts of genes and their roles in the life of organisms. The study of molecular genetics will lay the foundation for students to study further in the field of biotechnology and be aware of its impact on society.

The study of biodiversity will help students to recognise its complexity and the adaptations of different groups of organisms to their environment. Moreover, a phylogenetic approach to the classification system is adopted, which helps them to understand the development of the classification system with evidence gathered from molecular genetics. This will enable students to appreciate the phenomena of evolution and develop their curiosity about the origins of life. In addition to Darwin's theory, students are encouraged to explore other scientific explanations for the origins of life and evolution, to help illustrate the dynamic nature of scientific knowledge.

Scientific Inquiry

This should enable students to:

- make careful observations and accurate records (e.g. observe distinguishing features for identifying organisms, and variations in humans);
- use appropriate instruments and proper techniques for carrying out practical work on molecular genetics (e.g. DNA extraction and gel-electrophoresis);
- classify, collate and display both first and second hand data (e.g. construct a pedigree of the inheritance of some human traits);
- use diagrams and physical models as visual representations of phenomena and relationships arising from the data (e.g. genetic diagrams and DNA model); and
- formulate and revise scientific explanations and models using logic and evidence (e.g. use of fossil records as evidence for evolution).

STSE Connections

This should enable students to:

- be aware of the application of knowledge of basic and molecular genetics in society and its social, ethical and economic implications;
- be aware that societal needs have led to technological advances (e.g. recombinant DNA technology and DNA fingerprinting);
- appreciate the contribution of the Human Genome Project (HGP) and the application of biotechnology to humans and society;
- appreciate the role of science and technology in understanding the complexity of life forms and their genetics;
- understand how science has been influenced by societies (e.g. various views on the origins of life and evolution); and
- explain how the knowledge of biotechnology may lead to the development of new technologies and how new technologies may lead to further understanding of inheritance.

Nature and History of Biology

This should enable students to:

- be aware of the dynamic nature of biological knowledge (e.g. from basic genetics to molecular genetics, and the development of classification systems);
- recognise the contributions of various people (e.g. Gregor Mendel, James Watson, Francis Crick, Charles Darwin, Sir Alfred Russel Wallace and Jean Baptiste Lamarck) to the understanding of genetics and evolution;
- appreciate the advancement of the study of genetics from traditional breeding experiments to molecular experimentation and analysis; and
- be aware that biological knowledge and theories are developed through observations, hypotheses, experimentations and analyses (e.g. Mendel's work).

Students should learn	Students should be able to
a. Basic genetics	
Mendel's laws of inheritance	• Understand the law of segregation and law of independent assortment. • Apply Mendel's laws of inheritance to solve genetic problems.
Inheritance in humans • Multiple alleles: ABO blood groups • Sex linkage • Sex determination	• Understand the inheritance of ABO blood groups and sex-linked traits. • Recognise the role of sex chromosomes in sex determination of humans.
Pedigree analysis	• Analyse pedigree to study the inheritance of characteristics.
Variations in characteristics • Continuous variation • Discontinuous variation • Causes of variation – hereditary information – environmental factors – mutation	• Explain the causes of different types of variations in characteristics.
b. Molecular genetics	
Chromosomes, genes and nucleic acids	• Describe the structural and functional relationships of chromosomes, genes and nucleic acids.
Gene expression and protein synthesis • transcription and translation	• Outline the process of protein synthesis.
Mutation • Chromosome mutation (e.g. Down syndrome) and gene mutation (e.g. Sickle-cell anaemia) • Spontaneous and induced mutation • Causes of mutation (e.g. radiation and chemical)	• Distinguish between chromosome and gene mutation. • Recognise the applications of recombinant DNA technology and DNA fingerprinting. • Recognise the contributions and limitations of the data obtained from the HGP. • Appreciate the joint effort of scientists in international genomics projects.
Biotechnology • Recombinant DNA technology • DNA fingerprinting • Human Genome Project (HGP) and its implications	

Students should learn	Students should be able to
c. Biodiversity and evolution	
Diversity of life forms Classification of organisms • Need for classification • Classification approaches proposed by Carl Woese – Six kingdoms (Eubacteria, Archaebacteria, Protista, Fungi, Plantae and Animalia) – Three domains (Bacteria, Archaea and Eukarya) Origins of life Evolution • Origin of species • Speciation – genetic variation – isolation • Mechanism of evolution – natural selection • Evidence of evolution (e.g. fossil record)	• Appreciate the existence of various life forms in the world, and the different ways through which organisms adapt to their habitats. • Be aware that modern classification is based on the phylogenetic relationships of organisms. • Appreciate that classification systems are subject to change when new evidence appears. • Recognise the use of classification systems and binomial nomenclature. • Construct and use dichotomous keys to identify unknown organisms. • Classify organisms into six kingdoms. • Appreciate that there are various explanations for the origins of life. • Be aware of the limitations of using fossil record as evidence of evolution, and the presence of other evidence. • Relate speciation to evolution. • Outline the mechanism of evolution.

Suggested Learning and Teaching Activities

a. Basic genetics

- Read articles about how Gregor Mendel contributed to the study of genetics.
- Use computer simulations and other materials (e.g. genetic corn) to study patterns of inheritance.
- Observe and analyse variations in humans (e.g. height and tongue rolling).
- Construct and/or analyse a pedigree of the inheritance of some human traits (e.g. haemophilia, tongue rolling and ear lobes).

b. Molecular genetics

- Construct models of DNA and RNA.
- Read about the work of some biologists (e.g. James Watson and Francis Crick) in the discovery of DNA.
- Examine photomicrographs of karyotypes of chromosome mutation.
- Search for information on the sources of mutagenic agents and their effects on human health.
- Use audiovisual materials to illustrate the processes of recombinant DNA technology and DNA fingerprinting.
- Perform practical work to extract DNA from living tissues (e.g. onion tissues); and to separate DNA fragments by gel-electrophoresis.
- Search for information on the use of DNA fingerprinting in forensic science.
- Make a chart or create a timeline of the discoveries that have arisen from the HGP.

c. Biodiversity and evolution

- Visit a herbarium, country park or special area (e.g. Lions Nature Education Centre, and Tai Po Kau Nature Reserve).
- Use specimens, audiovisual materials, games, etc. to study the diversity of organisms, and their ways of life.
- Classify organisms into major categories according to a classification system.
- Discuss the advantages and limitations of different classification systems, and why the classification of some organisms has been changed over time.
- Search for information on other classification systems; and binomial naming of some organisms.
- Construct and use dichotomous keys to identify organisms from a local habitat.
- Read about the work of Carl Linnaeus and his system of naming organisms; the different explanations for the origins of life; and the work of some biologists (e.g. Jean Baptiste Lamarck, Charles Darwin and Sir Alfred Russel Wallace) on evolution.
- Use computer simulations or other simulations to model natural selection.

COMPULSORY PART

III. Organisms and Environment

Overview

Organisms are an integral part of the environment. Their ways of life and living are closely related to the environment where they live in. Based on this perspective, students will gain knowledge and understanding of organisms and their environment.

Firstly, students will study how organisms obtain their basic needs for oxygen, water and food from the environment. Life processes, such as nutrition, gas exchange, and transport involved, will be studied in an integrated manner so as to enhance understanding of the structures and functions of an organism as a whole. Secondly, students will study reproduction, growth and development to understand how organisms perpetuate and proliferate in the environment. The human is used as a model for students to understand the essential life processes of animals. Thirdly, students will examine how organisms detect changes in the environment and make appropriate responses for their survival, and how humans maintain a steady internal environment. Students will then explore how organisms interact with each other and with their environment as a whole. Finally, the dynamic nature of the ecosystems that involves energy flow and materials cycling will also be investigated. Students are expected to develop an awareness of the impact of human activities on the ecosystems and recognise the need for conservation.

Scientific Inquiry

This should enable students to:

- make careful observations and accurate records (e.g. examine prepared slides or temporary mounts of roots, stems and leaves, and make biological drawings);
- ask relevant questions, identify problems and formulate hypotheses for investigations related to life processes and ecosystems;
- plan, conduct and write reports on scientific investigations in areas of life processes and ecosystems;
- select and design appropriate methods of investigations for specific purposes (e.g. use transects and quadrats to collect samples in field studies);
- identify and explain the importance of control variables in scientific investigations (e.g. the study of the effects of different minerals on plant growth, and the action of digestive enzymes);
- explain why sample size, random sampling, replicates and repeat procedures are important in scientific investigations (e.g. field studies);

- use appropriate instruments and proper techniques for carrying out practical work (e.g. food tests, preparation of temporary mounts, microscopic examinations, dissections and field study techniques); and
- use diagrams, graphs, flow charts and physical models as visual representations of phenomena and relationships arising from the data (e.g. use food chains, food webs, and pyramid of numbers to represent relationships between organisms in ecosystems and distribution of organisms).

STSE Connections

This should enable students to:

- evaluate the impact of the application of biology to human activities (e.g. dietary requirement, birth control and pollution control);
- analyse ways in which scientific and technological advancement (e.g. computing technology and image analysing technology) have enhanced our understanding of complex life processes;
- develop sensitivity and responsibility in striking a balance between the needs of humans and a sustainable environment; and
- be aware of the application of biological knowledge (e.g. balanced diet, birth control, and sewage treatment) in society and its social, ethical, economic and environmental implications.

Nature and History of Biology

This should enable students to:

- understand that science is a human endeavour through the study of essential life processes of organisms and interactions with our environment;
- be aware that biological knowledge and theories are developed through observations, hypotheses, experimentations and analyses (e.g. the study of tropism, transpiration pull and field ecology);
- recognise the complexity of the physiological processes of organisms and the environment; and
- understand the nature and limitations of scientific activity (e.g. investigations on various physiological processes and ecosystems).

Students should learn	Students should be able to
a. Essential life processes in plants	
Nutrition in plants • Plants as autotrophs • Photosynthesis* • Need for minerals • Absorption of water and minerals	• Appreciate the significance of plants as autotrophs. • Explain the need for minerals in plants. • Relate the structure of roots to their functions in water absorption.
Gas exchange in plants • Occurrence of gas exchange in different parts of plant • Gas exchange in leaves	• Relate the features of leaves to gas exchange and prevention of water loss. • Explain the effects of light intensity on gas exchange in plants.
Transpiration • Process and significance • Factors (humidity, light intensity and wind) affecting the rate of transpiration	• Make connections between transpiration, absorption and transport of water, and cooling of plants. • Explain the effects of environmental factors on the rate of transpiration.
Transport of substances in plants • Transport of water and minerals • Translocation of organic nutrients	• Describe the path of materials transport in flowering plants. • Compare the means of support in herbaceous and woody dicotyledonous plants.
Support in plants • Cell turgidity • Physical nature of xylem	
b. Essential life processes in animals	
Nutrition in humans • Humans as heterotrophs • Food requirements and functions of different food substances – Carbohydrates – Lipids – Proteins – Vitamins – Minerals (e.g. calcium and iron) – Dietary fibre	• Explain the effect of age, activity and pregnancy on dietary requirements. • Relate health problems to improper diet. • Explain the significance of mechanical and chemical digestion. • Understand the digestion and absorption processes in various parts of the alimentary canal. • Illustrate the adaptive features of the small intestine for food absorption.

* Refer to *Photosynthesis* in topic I Cells and Molecules of Life

Students should learn	Students should be able to
• Balanced diet • Ingestion – Dentition – Mastication • Digestion – General plan of the digestive system – Digestion of carbohydrates, proteins and lipids in various parts of the alimentary canal • Absorption and assimilation – Structural adaptation of small intestine for food absorption – Role of liver – Fate of absorbed food • Egestion	• Describe the routes of the transport of absorbed food and their fates in cells and tissues.
Gas exchange in humans • General plan of the breathing system • Gas exchange in air sacs • Routes of transport of respiratory gases • Mechanism of ventilation	• Understand the exchange of respiratory gases between the body cells and the external environment. • Relate the structure of various parts of the breathing system to gas exchange.
Transport of substances in humans • General plan of the circulatory system and lymphatic system • Composition and functions of blood, tissue fluid and lymph • Exchange of materials between blood and body cells • Formation of tissue fluid	• Relate the structure of various components of the circulatory system and lymphatic system to transport. • Describe the exchange of materials and the formation of tissue fluid.
c. Reproduction, growth and development	
Asexual reproduction • Binary fission in bacteria • Vegetative propagation in flowering plants	• Outline with an example, the process of vegetative propagation in flowering plants. • Relate the structure of various floral parts to reproduction.
Sexual reproduction in flowering plants • Floral parts • Pollination • Fertilisation	• Understand the importance of pollination. • Compare the adaptive features of insect-pollinated flowers and wind-pollinated flowers.

Students should learn	Students should be able to
• Significance of seed and fruit dispersal	• Outline the process of fertilisation leading to the formation of seed and fruit. • Discuss the significance of asexual and sexual reproduction.
Reproduction in humans • General plan of the male and female reproductive systems • Structure of sperm and ovum • Menstrual cycle – Cyclic changes in uterine lining – Ovulation • Fertilisation • Development of embryo and foetus – Placenta • Identical twins and fraternal twins • Birth process • Parental care • Birth control	• Relate the structure of various parts of the reproductive systems to their functions. • Recognise the roles of sperm and ovum in sexual reproduction. • Describe the transfer of semen during sexual intercourse and the process of fertilisation. • Relate the structure of the placenta to its role in the development of foetus. • Recognise the significance of parental care and the advantages of breast-feeding. • Understand the biological basis of various methods of birth control.
Growth and development • Concepts of growth and development • Germination of seed and its development into a new plant • Stages of growth in annual plants and humans • Measurement of growth in plants and humans – Growth parameters (e.g. weight, height and area) – Growth curves	• Discuss the advantages and disadvantages of using various parameters to measure growth. • Identify the different stages of growth from growth curves of plants and humans.
d. Coordination and response	
Stimuli, receptors and responses • Light as stimulus: the human eye – Major parts of the eye – Rod cells and cone cells – Colour vision – Eye accommodation	• Understand the roles of sense organs and receptors in detecting changes in the environment. • Relate the structure of major parts of the eye to vision.

Students should learn	Students should be able to
– Eye defects (long sight, short sight and colour blindness) • Light as stimulus: phototropic response in plants – Responses of root and shoot – Role of auxins • Sound as stimulus: the human ear – Major parts of the ear	• Explain the causes of eye defects. • Describe how long sight and short sight are corrected with glasses. • Be aware of the surgical methods for eyesight correction. • Recognise the significance of phototropism. • Understand the mechanism of phototropic responses in root and shoot. • Relate the structure of major parts of the ear to hearing.
Nervous coordination in humans • General plan of the nervous system • Central nervous system – Functions of main parts of the brain: cerebrum, cerebellum and medulla oblongata – Functions of spinal cord – Neurone: sensory neurone, interneurone and motor neurone – Synapse • Reflex arc and reflex action • Voluntary actions	• Recognise the role of the central nervous system. • Distinguish different types of neurones in terms of structure and function. • Describe the transmission of nerve impulses across a synapse. • Compare the nature of reflexes and voluntary actions with examples.
Hormonal coordination in humans • Nature of hormonal coordination • General plan of the endocrine system	• Understand the nature of hormonal coordination. • Use an example to illustrate hormone mediated response. • Compare hormonal and nervous coordination.
Movement in humans • Components of the musculo-skeletal system: skeleton, muscles, joints, tendons and ligaments • Joints: hinge joints (e.g. elbow/knee) and ball-and-socket joints (e.g. shoulder/hip) • Action of opposing muscle pairs • Initiation of muscle contraction by nerve impulse	• Understand the roles of different components of the musculo-skeletal system. • Compare the degree of movement between hinge joints and ball-and-socket joints. • Describe how a nerve impulse transmits across the neuromuscular junction leading to muscle contraction. • Explain coordination in terms of stimulus, receptor, coordination system, effector and response.

Students should learn	Students should be able to
e. Homeostasis	
Concept of homeostasis • Importance of homeostasis • Feedback mechanism	• Explain the principle of feedback mechanism with reference to the regulation of blood glucose level. • Appreciate that the internal environment of the human body is maintained by the nervous system and the endocrine system.
Parameters of the internal environment • Glucose level and gas content in blood, water content and body temperature	
Regulation of blood glucose level • Roles of liver, pancreas, insulin and glucagon	
f. Ecosystems	
Levels of organisation • Species, population, community, ecosystem, biome and biosphere	• Be aware that organisms and their environment are studied at different levels of organisation. • Appreciate the existence of a variety of ecosystems in the local environment.
Major ecosystem types • Freshwater stream, rocky shore, mangrove, grassland and woodland	
Components of an ecosystem • Abiotic factors • Biotic community – Niche and habitat – Species diversity and dominant species – Relationships between organisms ▪ Predation, competition, commensalism, mutualism and parasitism – Ecological succession ▪ Primary and secondary succession ▪ Climax community	• Identify the abiotic factors of a habitat and explain their effects. • Describe the different types of relationships between organisms in a habitat. • Outline the process of ecological succession. • Use food chains, food webs, pyramids of numbers and biomass to represent the feeding relationships of organisms and energy flow between different trophic levels. • Understand the efficiency of energy transfer in an ecosystem. • Understand the cycling of materials in an ecosystem. • Be aware of the interactions between the biotic community and the abiotic factors of an ecosystem.

Students should learn	Students should be able to
Functioning of an ecosystem • Energy flow – Source of energy – Energy flow between different trophic levels – Feeding relationships of organisms • Materials cycling – Carbon and nitrogen cycles • Roles of producers, consumers and decomposers in energy flow and materials cycling	
Conservation of ecosystem • Impacts of human activities	• Recognise the need for conservation.
Study of a local habitat • Distribution and abundance of organisms – Sampling methods ▪ Quadrats ▪ Line and belt transects • Measurement of abiotic factors (e.g. light intensity, pH, wind, temperature, oxygen, humidity and salinity)	• Conduct and report an ecological study of a local habitat.

Suggested Learning and Teaching Activities

a. Essential life processes in plants

- Design and perform investigations to study the effects of different minerals on plant growth using potted plants; to study the effects of light intensity on gas exchange in land or water plants using hydrogencarbonate indicator solution or data loggers; to compare the distribution of stomata on both sides of a leaf; and to study the effects of environmental factors on the rate of transpiration using potometer.
- Examine the cross sections of the leaf, stem and root of a young dicotyledonous plant using temporary mounts or prepared slides; and the structure of the root of young seedlings using live specimens or prepared slides.
- Perform practical work to demonstrate the occurrence of transpiration; and to trace the uptake of water in herbaceous plant using eosin solution.

b. Essential life processes in animals

- Perform practical work to identify composition in some common foodstuffs; to demonstrate the effect of bile salt on oil; to simulate digestion and absorption in the alimentary canal using dialysis tubing; and to compare the differences in composition between inhaled and exhaled air.
- Design and perform investigations to compare the amount of vitamin C in different fruits and vegetables; and to study the action of digestive enzymes (e.g. amylase on starch-agar plate, protease on milk-agar plate or egg white).
- Examine the alimentary canal and its associated glands, and the breathing system of a dissected mammal or a human torso.
- Examine a pig's lungs; and the capillary flow in a fish's tail fin or frog's web.
- Examine the structure of air sacs, arteries and veins, and the components of blood using prepared slides or photomicrographs.
- Perform dissection of a pig's heart and examine its structures.

c. Reproduction, growth and development

- Examine photomicrographs, video clips or live cell images of binary fission of bacteria, sperms and ova.
- Use audiovisual materials to study the process of fertilisation.
- Examine the adaptive features of insect-pollinated and wind-pollinated flowers.
- Examine the male and female reproductive systems of dissected mammals or a human torso.
- Examine photos or video clips taken by ultrasound showing different stages of foetal development.
- Cultivate and examine any vegetative propagation organ of flowering plants.
- Search for information on the effectiveness and possible side effects of various birth control methods; *in vitro* fertilisation and termination of pregnancy.
- Discuss the harmful effects of drinking and smoking habits of a pregnant woman on the development of the foetus.
- Design and perform investigations to study seed germination and the growth of young seedlings.

d. Coordination and response

- Perform dissection of an ox's eye and examine its structures.
- Search for information on how modern technology helps in rectifying eye defects (e.g. short/long sight, astigmatism, cataract or glaucoma).
- Examine models of the human brain, eye, ear and arm.
- Design and perform investigations on the phototropic responses of roots and shoots.
- Perform practical work to observe the contraction of teased muscle from the leg of a pithed frog.

e. Homeostasis

- Construct a flow chart to illustrate the feedback mechanism.
- Search for information about the physiological consequences of hormonal imbalance (e.g. insulin) and the remedies, especially through modern advances in science and technology.

f. Ecosystems

- Visit nature reserves, country parks, marine parks, field study centres and other local habitats.
- Construct and interpret food chains, food webs, and pyramids of numbers and biomass.
- Use live or audiovisual materials to show the relationships of organisms in an ecosystem.
- Conduct an ecological study of a local habitat (e.g. freshwater stream and rocky shore).

COMPULSORY PART

IV. Health and Diseases

Overview

Students will acquire knowledge and develop an understanding of what constitutes health; so that they can make informed decisions on the choice of lifestyles, habits, and disease prevention measures. This is designed to help students develop a positive attitude towards health and be aware of both individual and public responsibility for the maintenance of a healthy community. The routes of pathogen transmission and the causes of some non-infectious diseases are to be learned in association with the biological principles that may lead to their prevention and control. The physiological defence mechanisms employed by the human body to combat diseases, the principle of vaccination, the use of antibiotics, and some of the related issues, are also discussed.

Scientific Inquiry

This should enable students to:

- make careful observations and accurate records (e.g. examine prepared slides or photomicrographs of pathogens and make biological drawings);
- identify questions and carry out appropriate studies to understand various infectious and non-infectious diseases in our society;
- classify, collate and display both first and second hand data (e.g. collect information related to health and diseases from the Hospital Authority, Department of Health or the Internet); and
- understand that the process of scientific investigations includes analysing evidence and providing explanations based upon scientific theories and concepts (e.g. body defence mechanisms, treatment and prevention of infectious diseases).

STSE Connections

This should enable students to:

- be aware of the application of biological knowledge in maintaining a healthy community and its social, ethical, economic and environmental implications;
- analyse ways in which societal needs have led to technological advances (e.g. treatment and prevention of diseases);
- appreciate how modern technological advances and scientific discoveries contribute to the detection, diagnosis, treatment, prevention and monitoring of diseases (e.g. cancer and tuberculosis); and
- be aware of personal responsibility in preventing disease transmission.

This should enable students to:

- be aware of the dynamic nature of biological knowledge related to body defence mechanism and diseases, and understand that science is a human endeavour;
- appreciate the contributions of various people in advancing the application of biology (e.g. the development of vaccines and the discovery of antibiotics);
- be aware that biological knowledge and theories related to the prevention and control of diseases are developed through observations, hypotheses, experimentations and analyses; and
- understand the nature and limitations of scientific activity (e.g. the causes and transmission of some diseases are not yet known).

Students should learn	Students should be able to
a. Personal health	
Meaning of health	• Recognise the meaning of health.
b. Diseases	
Types of diseases • Infectious diseases • Non-infectious diseases	• Understand the concept of disease. • Distinguish between infectious and non-infectious diseases.
Infectious diseases (e.g. Cholera, dengue fever, hepatitis B, influenza and tuberculosis) • Causes • Ways of transmission – Water, air, droplets, food, body fluids, vector and direct contact • Treatment – Antibiotics ▪ Action of antibiotics ▪ Indiscriminate use – Other drugs (e.g. sulpha drugs)	• Understand how infectious diseases are transmitted. • Discuss how to reduce the spread of some common infectious diseases. • Discuss the consequences of indiscriminate use of antibiotics. • Be aware of the various ways of disease treatment.
Non-infectious diseases • Cancer • Cardiovascular diseases (e.g. coronary heart disease) • Diabetes – Forms of diabetes (insulin-dependent diabetes and non-insulin-dependent diabetes) – Control of diabetes	• Discuss the causal relationships between the incidence of various non-infectious diseases and certain lifestyles. • Outline the biological principles in the control of insulin-dependent diabetes.
Prevention of diseases • Vaccination: principle of vaccination • Immunisation programme • Healthy lifestyle • Community health	• Outline the principle of vaccination and evaluate the advantages and risks of its application. • Be aware of personal responsibility in preventing disease transmission and the importance of community health.

Students should learn	Students should be able to
c. Body defence mechanisms	
Non-specific defence mechanisms • Skin, mucus and other secretions, cilia, phagocytes, blood clotting and inflammatory responses Specific defence mechanisms • Immune response • Antigen and antibody • Lymphocytes (B and T cells) • Primary and secondary responses • Active and passive immunity	• Understand the non-specific and specific defence mechanisms. • Outline the principles of immune response. • Compare primary and secondary responses. • Distinguish between active and passive immunity.

Suggested Learning and Teaching Activities

b. Diseases

- Examine photomicrographs, prepared slides or live cell images of some pathogens (e.g. viruses, bacteria, fungi and protists).
- Conduct a project on infectious diseases (e.g. Cholera, dengue fever, hepatitis B, influenza and tuberculosis) with reference to their ways of transmission, symptoms, treatments and ways of prevention; and the incidences of various types of cancer in Hong Kong.
- Conduct a study on the incidence of liver cancer and lung cancer in relation to lifestyles.
- Design a poster, leaflet or web page to advise how to reduce the chances of developing one form of cancer.
- Suggest ways to reduce the incidence of cardiovascular diseases.
- Search for information on the types, symptoms, risk factors, diagnosis, management and control of diabetes; the relation of immunisation programmes to the control of infectious diseases (e.g. whooping cough and tuberculosis), and the major outbreaks of infectious diseases in Hong Kong.
- Read stories about how scientists (e.g. Edward Jenner, Louis Pasteur and Jonas Salk) contributed to the development of vaccination.
- Read stories about how scientists (e.g. Sir Alexander Fleming, Ernst Boris Chain and Sir Howard Florey) contributed to the discovery and development of penicillin.
- Study a personal immunisation record to find out the types of diseases that are covered by the local immunisation programme.
- Use audiovisual materials to illustrate the effects of antibiotic discs on a bacterial lawn.

c. Body defence mechanisms

- Examine prepared slides or models to identify features of mammalian skin that are related to body defence.
- Use audiovisual materials, prepared slides, photomicrographs or live cell images to observe phagocytes and lymphocytes.
- Use audiovisual materials or animations to demonstrate the production of antibodies in response to an antigen, and the antigen-antibody reactions.
- Discuss why breast feeding may confer passive immunity on a child.

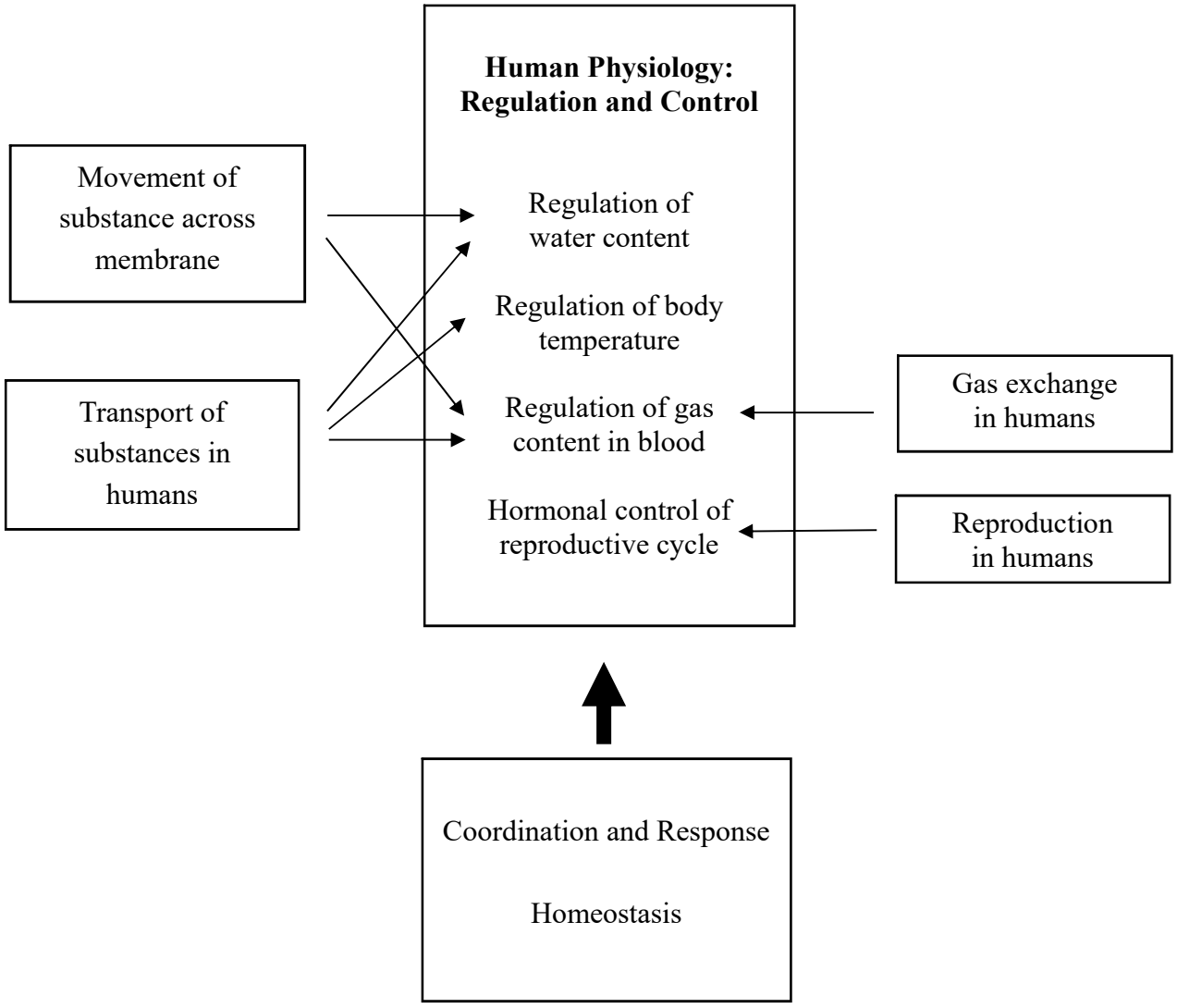
ELECTIVE PART

V. Human Physiology: Regulation and Control

Overview

In this topic, students will develop a deeper understanding of the physiological processes in humans. Regulation and control is an interesting topic concerning the intriguing mechanisms which enable our bodies to function normally regardless of the changes in environmental conditions. Students are expected to understand the roles of nervous control and hormonal control in coordinating different organs and systems to achieve a steady internal environment.

Human Physiology: Regulation and Control builds on students' prior knowledge of *Movement of substances across membrane*, *Essential life processes*, *Coordination and response* and *Homeostasis* studied in the compulsory part. The diagram below shows how the prior knowledge is related to this topic.



Scientific Inquiry

This should enable students to:

- ask relevant questions, identify problems and formulate hypotheses for investigations related to nervous and hormonal control of the human body;
- plan, conduct and write a report on a scientific investigation (e.g. study the change in heart rate and breathing rate before and after exercise);
- use appropriate instruments and proper techniques for carrying out practical work (e.g. measuring breathing rate and heart rate);
- make careful observations and accurate records; and
- classify, collate and display both first and second hand data (e.g. hormonal change in the menstrual cycle).

STSE Connections

This should enable students to:

- be aware of the significance of knowledge in human physiology to improve the quality of life and maintain a healthy community;
- be aware that societal needs have led to technological advances (e.g. dialysis machines and the use of contraceptives); and
- appreciate the role of science and technology in understanding the human body.

Nature and History of Biology

This should enable students to:

- be aware of the dynamic nature of biological knowledge in human physiology, and understand that science is a human endeavour; and
- be aware that biological knowledge and theories are developed through observations, hypotheses, experimentations and analyses.

Students should learn	Students should be able to
a. Regulation of water content (osmoregulation)	
Importance of regulation of water content Regulation of water content • General plan of the urinary system • Structure and function of nephron • Processes in urine formation – Ultrafiltration – Reabsorption • Action of antidiuretic hormone (ADH) • Biological principles of the dialysis machine (kidney machine)	• Relate the structure of nephron to its function in regulation of water content. • Understand the action of ADH. • Recognise the excretory function of the kidney.
b. Regulation of body temperature	
Importance of body temperature regulation Mechanisms of temperature regulation • Skin • Regulatory centre (hypothalamus) • Circulation • Hormone (thyroxine) • Muscle • Behavioural methods	• Understand the structural, physiological and behavioural mechanisms of body temperature regulation.
c. Regulation of gas content in blood	
Importance of regulation of gas content in blood Control of rate and depth of breathing • Nervous control – Respiratory centre and chemoreceptors – Effects of carbon dioxide concentration in blood Control of cardiac output • Heart rate and stroke volume • Pacemaker and cardiac cycle	• Understand the control mechanism of breathing. • Outline the major events during the cardiac cycle. • Understand the nervous and hormonal control of cardiac output. • Explain how the gas content in blood is regulated during and after exercise.

Students should learn	Students should be able to
• Nervous control – Vagus nerve and sympathetic nerves • Hormonal control – Adrenaline Effects of exercise • Rate and depth of breathing • Oxygen debt • Cardiac output	
d. Hormonal control of reproductive cycle	
Interaction of hormones in the menstrual cycle	• Understand the significance of hormonal control of the menstrual cycle.
Use of hormones as contraceptives and in the treatment of infertility	• Explain how hormones can be used as contraceptives and in the treatment of infertility.

Suggested Learning and Teaching Activities

a. Regulation of water content
- Examine a dissected mammalian kidney or a kidney model.
- Examine the urinary system of a dissected mammal or a human torso.

b. Regulation of body temperature
- Examine prepared slides or photomicrographs to identify features of mammalian skin that are related to temperature regulation.
- Construct a concept map to show the mechanism of temperature regulation.
- Search for information on human physiological conditions under extreme hot and cold environments.

c. Regulation of gas content in blood
- Design and perform investigations to study the changes in heart rate and breathing before and after exercise using data loggers or other methods.

d. Hormonal control of reproductive cycle
- Interpret graphs showing the fluctuation of hormones and the changes of the uterine lining of the menstrual cycle.
- Conduct a project on the causes of infertility and its treatment.

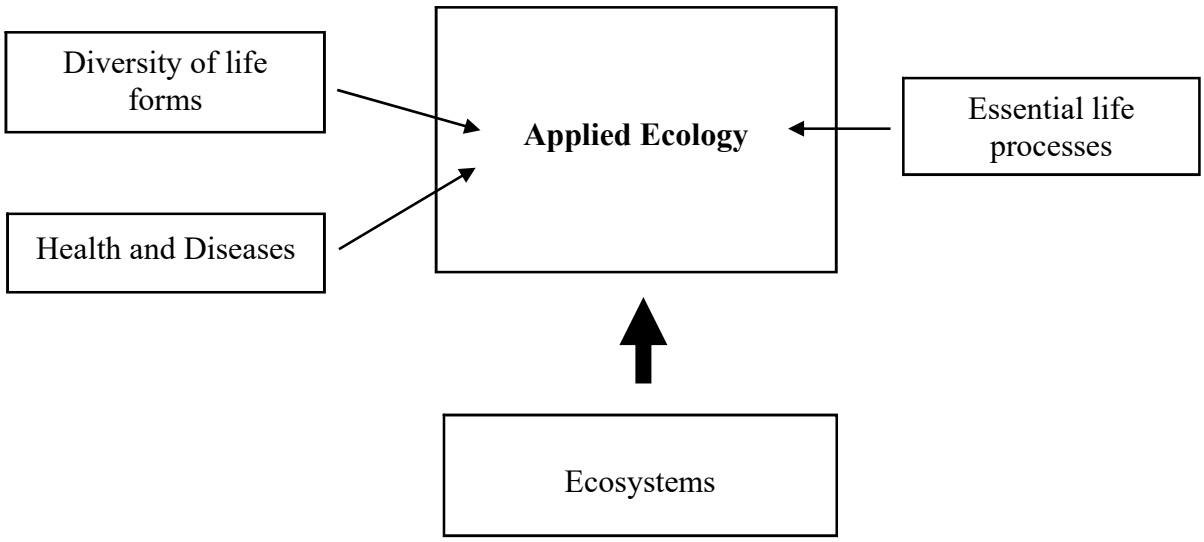
ELECTIVE PART

VI. Applied Ecology

Overview

In this topic, students will build on their prior knowledge of basic ecological principles and develop a further understanding of applied ecology. Students will explore some of the ways in which human activities can impose far-reaching effects on the environment. Local and global pollution issues, resources management, pollution control measures and conservation will be also discussed. At the end, students are expected to apply a range of field study skills to investigate the impact of pollution on the local environment.

Applied Ecology builds on students' prior knowledge of the *Diversity of life forms*, *Essential life processes*, *Ecosystems* and *Health and Diseases* studied in the compulsory part. The diagram below shows how the prior knowledge is related to this topic.



Scientific Inquiry

This should enable students to:

- make careful observations, ask relevant questions, identify problems and formulate hypotheses for investigations related to pollution;
- identify and explain the importance of control variables in scientific investigations related to pollution;
- explain why sample size, random sampling, replicates and repeat procedures are important in ecological investigations; and
- classify, collate, display, analyse and draw conclusions from both first and second hand data (e.g. collect field data, obtain data from the Environmental Protection Department, Agriculture, Fisheries and Conservation Department or the Internet).

STSE Connections

This should enable students to:

- be aware of the application of ecological knowledge in society and its social, ethical, economic and environmental implications;
- analyse ways in which scientific and technological advancement have influenced our lives, society and the environment (e.g. pollution resulting from industrialisation and urbanisation);
- develop sensitivity and responsibility in striking a balance between the needs of humans and a sustainable environment; and
- explain how biological knowledge is used in technological application for management of the environment (e.g. sewage treatment).

Nature and History of Biology

This should enable students to:

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

Students should learn	Students should be able to
a. Human impact on the environment	
Human population growth • Impact of rapid human population growth on the environment • Need for population control Use of resources • Types of resources: renewable and non-renewable resources • Fisheries and agriculture • Impacts – Overexploitation (e.g. in fisheries) – Environmental degradation (e.g. chemical pollution in agriculture) Effects of urbanisation and industrialisation • Land clearance and reclamation • Health problems related to pollution – Air pollution (e.g. respiratory illnesses) – Water pollution (e.g. gastroenteritis)	• Evaluate the impact and control of rapid human population growth. • Recognise the impacts of malpractices in fisheries and agriculture. • Explain the ecological impacts of land clearance and reclamation. • Recognise the effects of air and water pollution on the environment and human health. • Account for the accumulation of toxic substances along a food chain. • Design and perform investigation to study air or water pollution.
b. Pollution control	
Reduce, reuse, recycle and replace Sewage treatment	• Recognise strategies for pollution control. • Describe the biological principles of sewage treatment.
c. Conservation	
Importance of biodiversity Conservation of species • Endangered species in Hong Kong Measures to protect endangered species Conservation of habitats	• Understand the need for conservation. • Recognise measures to preserve biodiversity. • Be aware of the economic, ecological, aesthetic and moral issues related to conservation. • Discuss the roles of individuals and government in conservation.

Students should learn	Students should be able to
• Conservation areas (e.g. Sites of Special Scientific Interest (SSSI), country parks, marine parks and the Ramsar site) • Ecological restoration of damaged land	
d. Global issues	
• Sustainable development • Management of resources: fisheries and agriculture • Global warming • Acid rain • Eutrophication and algal boom	• Recognise the causes and problems of global issues. • Use local examples to illustrate how resources are managed.

Suggested Learning and Teaching Activities

a. Human impact on the environment

- Conduct a project on the effects of human population growth on the environment and the quality of life.
- Design and perform investigations to study the lichen distribution as an indication of air pollution by sulphur dioxide; to compare the oxygen content of clean and polluted water using data loggers or other means; and to study the types, sources and effects of pollutants on a freshwater stream or a shore habitat.
- Identify areas in Hong Kong in which air pollution is most serious, based on the available information from the Environmental Protection Department, and discuss the possible causes.

b. Pollution control

- Search for information on the joint efforts of governments to control regional air pollution problems.
- Develop action plans to reduce environmental pollution.
- Visit a sewage treatment plant.

c. Conservation

- Discuss the conservation of an endangered species with regard to population size, reasons for concern, measures introduced and international cooperation required; and the existing government policies on environmental conservation.
- Visit a conservation area in Hong Kong (e.g. Sites of Special Scientific Interest (SSSI), country parks, marine parks and the Ramsar site).
- Search for information on the work on conservation done by environmental concern groups and the government.
- Debate on the dilemma between urbanisation, industrialisation and conservation.

d. Global issues

- Conduct a project on the issues related to global warming and acid rain.
- Research into some local examples which illustrate the conflicting interests between economic development and environmental conservation.

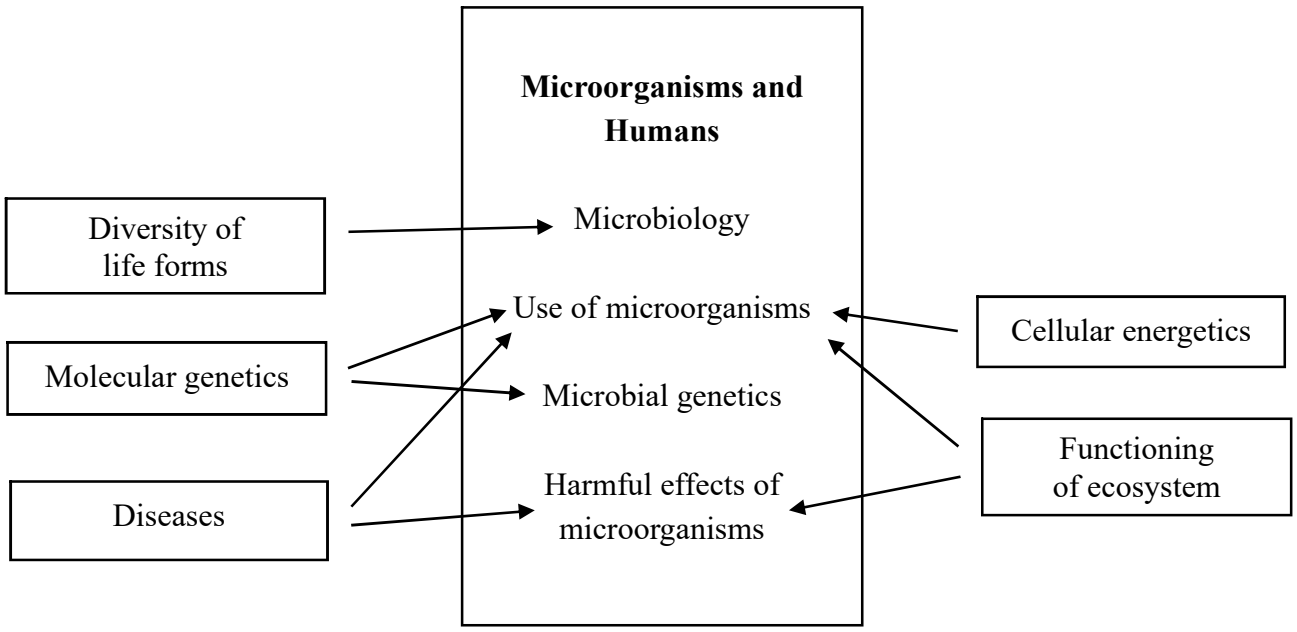
ELECTIVE PART

VII. Microorganisms and Humans

Overview

Humans are living in a world full of microorganisms, and our daily lives are directly and indirectly affected by them. In this topic, students will develop an understanding of the diversity of microorganisms, and their beneficial and harmful roles. Students will have the opportunity to study the growth of microorganisms, and develop appropriate laboratory skills and techniques for conducting practical work with microorganisms. Examples of uses of microorganisms in food, medicine, industry pollution control and genetic engineering are included, so as to illustrate the importance of microorganisms and their wide applications. Finally, human diseases caused by pathogenic microorganisms, and microbial deterioration are used to illustrate the harmful effects of microorganisms.

Microorganisms and Humans builds on students' prior knowledge of *Cellular energetics*, *Molecular genetics*, *Diversity of life forms*, *Functioning of ecosystem*, and *Diseases* studied in the compulsory part. The diagram below shows how the prior knowledge is related to this topic.



Scientific Inquiry

This should enable students to:

- make careful observations, ask relevant questions, identify problems and formulate hypotheses for investigations related to the study of microorganisms;
- plan, conduct and write a report on an investigation (e.g. study the optimal conditions for fermentation);
- use appropriate instruments and proper techniques for carrying out practical work (e.g. aseptic techniques and measuring the growth of yeast);
- identify and explain the importance of control variables in scientific investigations related to microbiology; and
- classify, collate and display both first and second hand data (e.g. collect data from the Hospital Authority, Department of Health and World Health Organisation).

STSE Connections

This should enable students to:

- be aware of the influences of various types of microorganisms on society and the environment (e.g. as pathogens, decomposers);
- be aware of the applications of knowledge of microorganisms and their social, economic and environmental implications (e.g. the use of bacteria in biotechnology);
- analyse ways in which scientific and technological advancement have enhanced our understanding in microbiology(e.g. aseptic techniques, recombinant DNA technology); and
- explain how biological knowledge is used in technological application (e.g. the use of microorganisms in sewage treatment).

Nature and History of Biology

This should enable students to:

- be aware of the dynamic nature of biological knowledge related to microorganisms and understand that the development of microbiology is a human endeavour;
- appreciate the contributions of various people in advancing the application of biology (e.g. the development of vaccines and the discoveries of antibiotics); and
- understand the nature and limitations of scientific activity.

Students should learn	Students should be able to
a. Microbiology	
Viruses • Multiplication of viruses	• Describe how a virus reproduces by infecting a living cell.
Diversity of microorganisms • Representative organisms of Bacteria, Protista and Fungi	• Distinguish different groups of microorganisms based on group features. • Discuss the effects of environmental factors on the growth of microorganisms.
Growth of microorganisms (e.g. yeast) • Growth requirement – Temperature, pH, carbon and nitrogen sources, oxygen and water availability • Stages of growth • Measurement of growth – Cell counts, biomass and optical methods	• Measure and identify the different stages of growth of microorganisms in culture. • Outline the principle of aseptic techniques. • Use aseptic techniques and follow safety procedures in handling, culturing and disposing of microorganisms.
Aseptic techniques • Principles • Precautions and risk assessment	
b. Use of microorganisms	
Food processing (e.g. beer-brewing) Vaccines Antibiotics Industrial enzymes (e.g. biological washing powder and pectinase for extracting fruit juice) Sewage treatment Biogas production	• Outline the process of food production involving the use of microorganisms in fermentation. • Understand the roles of microorganisms in sewage treatment. • Be aware of the wide applications of microorganisms.

Students should learn	Students should be able to
c. Microbial genetics	
Genetically modified microorganisms (e.g. bacteria and yeast)	• Be aware of the significance and potential hazards of the application of genetically modified microorganisms.
d. Harmful effects of microorganisms	• Outline the principles of how microorganisms cause diseases in humans.
Diseases caused by microorganisms • Food-borne infection and food poisoning	• Recognise the causes of food-borne infection and food poisoning.
Microbial deterioration	• Recognise the problems of microbial deterioration to our daily lives.
Control of growth of microorganisms	• Discuss how to control and eliminate the harmful effects of microorganisms.

Suggested Learning and Teaching Activities

a. Microbiology

- Perform practical work to demonstrate aseptic techniques; and to grow yeast in liquid culture and on agar.
- Design and perform investigations to study the growth of microorganisms (e.g. yeast).

b. Use of microorganisms

- Visit a food production plant or a sewage treatment plant.
- Conduct a project on the applications of microorganisms.
- Perform practical work on the application of the fermentation process (e.g. bread-making, fruit juice fermenting, beer-brewing and wine-making).
- Design and perform investigations to study the optimal conditions necessary for fermentation by yeast in bread-making or beer-brewing; and to study the content and effectiveness of biological and non-biological washing powder.

c. Microbial genetics

- Search for information on the wide application of genetically modified microorganisms.

d. Harmful effects of microorganisms

- Search for information on the incidence of food poisoning in Hong Kong.
- Conduct a project on the prevention of microbial deterioration.

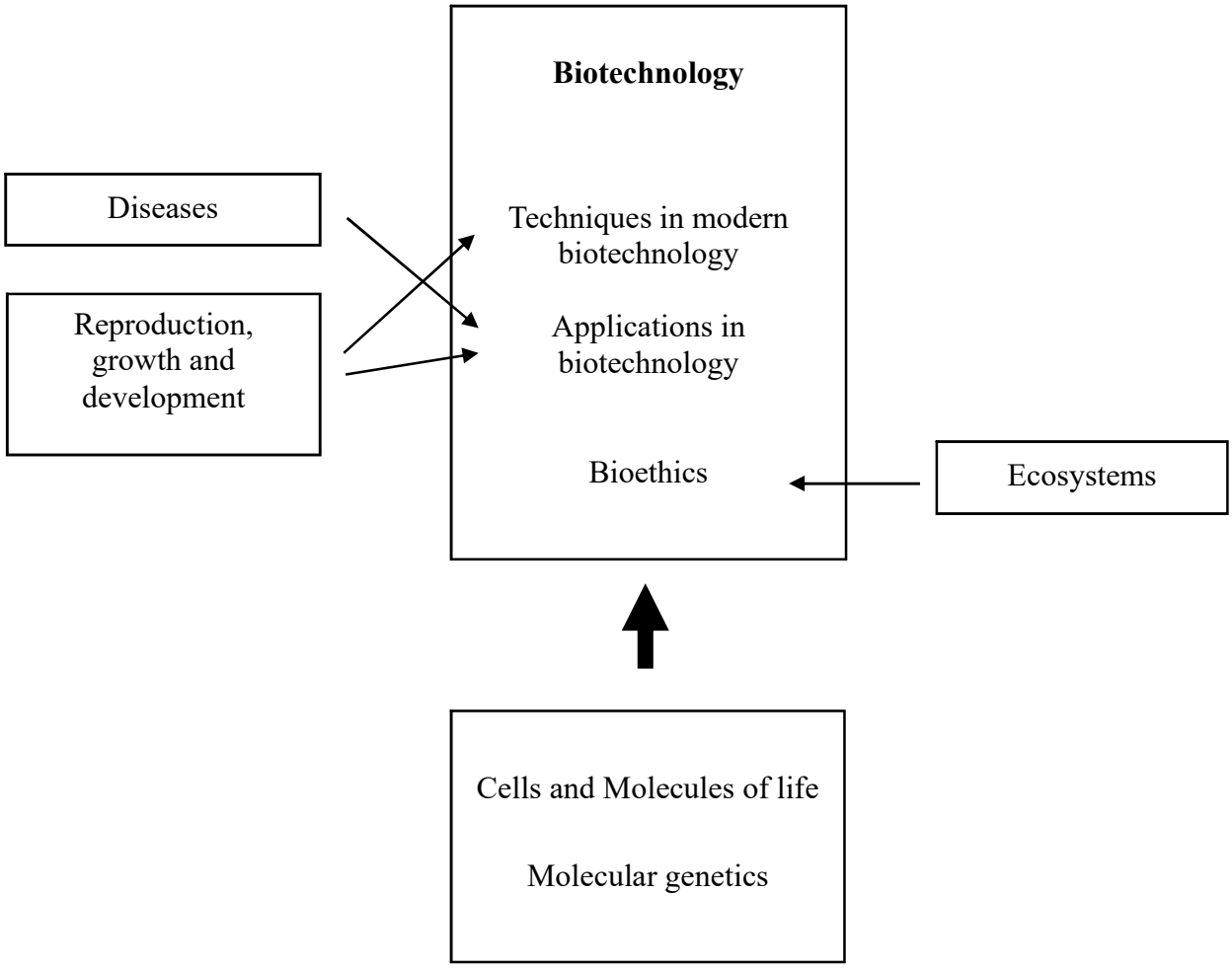
ELECTIVE PART

VIII. Biotechnology

Overview

This topic is expected to provide students with opportunities to study the general principles of biotechnology and its wide range of applications. This will enable them to recognise biotechnology as a rapidly expanding branch of Biology. Students will first develop an understanding of the principles of different techniques in modern biotechnology, e.g. recombination DNA technology, polymerase chain reaction, genetically modification of organisms, plants and animal cloning. They will also become familiar with the applications of biotechnology in the area of medicine and agriculture, and be aware of the ethical, legal, social, economic and environmental implications of biotechnology. Current issues, research and developments in biotechnology, as well as the contribution of biotechnology to the advancement of biology will also be discussed.

Biotechnology builds on students' prior knowledge of *Cells and Molecules of Life*; *Molecular genetics*; *Reproduction*, *growth and development; Ecosystems* and *Diseases* studied in the compulsory part. The diagram below shows how the prior knowledge is related to this topic.



Scientific Inquiry

This should enable students to:

- use appropriate instruments and proper techniques for carrying out practical work (e.g. separation of DNA fragments by gel-electrophoresis and amplification of DNA fragments by PCR); and
- analyse and draw conclusions from data (e.g. DNA fingerprinting).

STSE Connections

This should enable students to:

- be aware of the wide application of biotechnology and its social, ethical, economic and environmental implications (e.g. issues related to stem cells therapy, gene therapy, animal cloning and genetically modified food);
- explain how scientific knowledge may lead to the development of new technology and how new technology may lead to scientific discovery (e.g. understanding of the characteristics of enzymes leading to the invention of PCR technology);
- appreciate the role of science and technology in understanding the inheritance of humans;
- be aware that societal needs have led to technological advances (e.g. the production of genetically modified crops to solve food shortage problem) ; and
- understand how science has been influenced by societies (e.g. debates on human cloning and human stem cells research).

Nature and History of Biology

This should enable students to:

- be aware of the dynamic nature of biological knowledge related to biotechnology and understand that biotechnology is a human endeavour;
- recognise the contributions of various people in biotechnology (e.g. Herbert Boyer and Stanley Cohen - development of recombinant DNA technology, Kary Mullis - invention of the PCR technique, and Alec Jeffreys - development of DNA fingerprinting); and
- appreciate the joint efforts of scientists in the development of biotechnology (e.g. the scientists in the US, the UK, France, Germany, Japan and China have contributed to the HGP).

Students should learn	Students should be able to
a. Techniques in modern biotechnology	
Process of recombinant DNA technology • the production of insulin Polymerase chain reaction (PCR) and its application DNA fingerprinting and its application Genetically modified organisms • Principles of producing genetically modified microorganisms, animals and plants Animal cloning • Major steps in cloning of mammals (e.g. Dolly the sheep) Plant cloning • Major steps in plant tissue culture	• Outline the principles of recombinant DNA technology, PCR, DNA fingerprinting, constructing genetically modified organisms, cloning of mammals, and plant tissue culture. • Recognise the wide application of PCR. • Discuss the benefits and hazards of genetic engineering. • Be aware of the advantages, disadvantages, applications and limitations of cloning in animals and plants.
b. Applications in biotechnology	
Production of pharmaceutical products (e.g. Insulin, human growth hormone, vaccine and monoclonal antibodies) Gene therapy • Somatic cell gene therapy Stem cells therapy • Nature of stem cells	• Understand the role of bacteria in the production of pharmaceutical products. • Recognise the possible benefits and hazards of gene therapy. • Recognise the potential application of stem cells in medicine.
Transgenic animals and plants	• Recognise the use of transgenic animals and plants in scientific research, food industry and agriculture.

Students should learn	Students should be able to
c. Bioethics Ethical, legal, social, economic and environmental issues Areas of current concern in biotechnology • Genetically modified food • Animal and plant cloning • Human Genome Project • Gene therapy • Stem cells therapy	• Be aware of the potential impact of biotechnology on society. • Discuss the issues related to one of the areas of concern in biotechnology.

Suggested Learning and Teaching Activities

a. Techniques in modern biotechnology

- Perform practical work to amplify DNA fragments using PCR; and to separate DNA fragments by gel electrophoresis.
- Use diagrams, audiovisual materials or animations to illustrate the processes of recombinant DNA technology, PCR, DNA fingerprinting and cloning.
- Examine cases or discuss the use of DNA fingerprinting in forensic science.
- Read articles about the contributions of scientists which have led to the development in genetic engineering (e.g. Kary Mullis, Alec Jeffreys, Herbert Boyer and Stanley Cohen).
- Search for information on animal or plant cloning.

b. Applications in biotechnology

- Read articles about the treatment of severe combined immunodeficiency disease (SCID) by means of gene therapy.
- Search for information on the application of biotechnology in the pharmaceutical industry.
- Search for information on the uses of transgenic plants in agriculture.
- Compare traditional breeding and genetic engineering in crop production.

c. Bioethics

- Debate on the issues related to genetically modified food, animal and plant cloning, HGP, gene therapy and stem cells therapy.
- Search for information on the ways in which scientists inform the public and debate their discoveries in cloning.

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