Biology, Grade 12, University Preparation (SBI4U)

This course provides students with the opportunity for in-depth study of the concepts and processes associated with biological systems. Students will study theory and conduct investigations in the areas of metabolic processes, molecular genetics, homeostasis, evolution, and population dynamics. Emphasis will be placed on achievement of the detailed knowledge and refined skills needed for further study in various branches of the life sciences and related fields.

Prerequisite: Biology, Grade 11, University Preparation

Throughout this course, students will:

- demonstrate an understanding of safety practices consistent with Workplace Hazardous Materials Information System (WHMIS) legislation by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., use proper techniques in handling, storing, and disposing of bacteria, chemicals, and bio-hazardous waste);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., use molecular models to represent functional groups; perform gel electrophoresis or DNA extraction);
- demonstrate the skills required to plan and carry out investigations, using laboratory equipment safely, effectively, and accurately (e.g., conduct an experiment to investigate the effect of temperature on enzymes);
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., use chemical formulae for biological molecules);
- locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites;
- compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams (e.g., create a chart of hormone actions, or of homologous and analogous structures; create a timeline of recent discoveries in biotechnology);
- communicate the procedures and results of investigations and research for specific purposes using data tables and laboratory reports (e.g., report on an experimental investigation of the effect of chemical stimuli on invertebrates, or the causes of fluctuation of a population);
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- select and use appropriate SI units;
- identify and describe science- and technology-based careers related to the subject area under study (e.g., genetic engineer, biochemist, genetic counsellor, microbiologist, pharmacologist, histologist, immunologist, palaeontologist, population ecologist, nutritionist).

Metabolic Processes

Overall Expectations

By the end of this course, students will:

- describe the structure and function of the macromolecules necessary for the normal metabolic functions of all living things, and the role of enzymes in maintaining normal metabolic functions;
- conduct laboratory investigations into the transformation of energy in the cell, including photosynthesis and cellular respiration, and into the chemical and physical properties of biological molecules;
- explain ways in which knowledge of the metabolic processes of living systems can contribute to technological development and affect community processes and personal choices in everyday life.

Specific Expectations

Understanding Basic Concepts

By the end of this course, students will:

- apply the laws of thermodynamics to the transfer of energy in the cell, particularly with respect to respiration and photosynthesis;
- identify the functional groups within biological molecules (e.g., hydroxyl, carbonyl, carboxyl, amino, phosphate) and explain how they contribute to the function of each molecule (e.g., use molecular models to determine whether a molecule is polar or non-polar, and relate this property to diffusion through a plasma membrane);
- describe the chemical structure, mechanisms, and dynamics of enzymes in cellular metabolism (e.g., the function of enzymes in metabolic reactions in mitochondria or chloroplasts);
- identify and describe the four main types of biochemical reactions: redox, hydrolysis, condensation, and neutralization;
- describe how such molecules as glucose, ATP, pyruvic acid, NADH, and oxygen function within energy transformations in the cell, and explain the roles of such cell components as mitochondria, chloroplasts, and enzymes in the processes of cellular respiration and photosynthesis;
- compare matter and energy transformations associated with the processes of cellular respiration (aerobic and anaerobic) and photosynthesis (e.g., for each process, compare the role of oxygen and the role of organelles, such as mitochondria and chloroplasts).

Developing Skills of Inquiry and Communication

By the end of this course, students will:

- formulate operational definitions of the terms related to metabolic processes (e.g., use the following terms in relation to cell metabolism: *electronegativity*, *isomer*, *functional group*, *polymer*, *organic acid*, *organic base*, *solubility*, *enzyme*, *substrate*, *reaction rate*);
- investigate the structures of biological molecules and functional groups using computer-generated, three-dimensional images and/or by building molecular models (e.g., simple carbohydrates, amino acids, simple polypeptides);
- investigate and explain the relationship between metabolism and the structure of biomolecules, using problem-solving techniques (e.g., analyse the difference between the metabolic rates of sweet corn and starchy corn);

- design and carry out an experiment related to a cell process (e.g., enzyme activity, membrane transport), controlling the major variables and adapting or extending procedures where required (e.g., conduct an experiment to find optimal conditions [pH, concentration, and temperature] for various enzymes and membrane transport);
- determine the similarities and differences between mitochondria and chloroplasts (e.g., compare the structure and function of a mitochondrion and a chloroplast by examining micrographs and identifying reactants, products, and pathways);
- interpret qualitative and quantitative observations, gathered through investigation, of the products of cellular respiration and photosynthesis (e.g., type and quantity produced) and, either by hand or by computer, compile and display the results in an appropriate format.

Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

- relate knowledge gained from their current studies of metabolism to their learning in the fields of chemical thermodynamics and physical energy;
- describe technological applications of enzyme activity in the food and pharmaceutical industries (e.g., the production of dairy products using micro-organisms; the use of yeast to make bread; the use of enzymes to control reaction rates in the pharmaceutical industry);
- explain the relevance, in their personal lives and the life of the community, of the study of cell biology and related technologies (e.g., explain how their learning about metabolic processes is relevant to their personal choices about exercise, diet, and the use of pharmacological substances).

Molecular Genetics

Overall Expectations

By the end of this course, students will:

- explain the concepts of gene and gene expression and the roles of DNA, RNA, and chromosomes in cellular metabolism, growth, and division, and demonstrate an awareness of the universality of the genetic code;
- explain, through laboratory activities and conceptual models, processes within the cell nucleus;
- describe some of the theoretical issues surrounding scientific research into genetic continuity; the general impact and philosophical implications of the knowledge gained; and some of the issues raised by related technological applications.

Specific Expectations

Understanding Basic Concepts

By the end of this course, students will:

– compare the structure and function of RNA and DNA, and explain their roles in protein synthesis;

– describe the current model of DNA replication and methods of repair following an error;

– explain the steps involved in protein synthesis (e.g., transcription and translation) and the control mechanisms for genetic expression using regulatory proteins (e.g., lac operon, tryp operon);

– describe how mutagens such as radiation and chemicals can change the genetic material in cells by causing mutations (e.g., point mutations and frame-shifts);

– demonstrate an understanding of genetic manipulation, and of its industrial and agricultural applications (e.g., describe the processes involved in cloning, or in sequencing of DNA bases; explain the processes involved in the manipulation of genetic material and protein synthesis; explain the development and mechanisms of the polymerization chain reaction);

– describe the functions of the cell components used in genetic engineering (e.g., the roles of plasmids, restriction enzymes, recombinant DNA, and vectors);

– outline contributions of genetic engineers, molecular biologists, and biochemists that have led to the further development of the field of genetics (e.g., the findings of Cohen-Boyer [1973], Chilton [1981], and Stanford [1988]; transfer of the somatotropine gene [1990]).

Developing Skills of Inquiry and Communication

By the end of this course, students will:

– illustrate the genetic code by examining/analysing a segment of DNA (e.g., compare base sequences of DNA for an enzyme in humans and another animal; compare base sequences in DNA in order to recognize an anomaly);

– interpret micrographs that demonstrate the cellular structures involved in protein synthesis;

– investigate and analyse the cell components involved in protein synthesis, using laboratory equipment safely and appropriately (e.g., extract DNA; compare different proteins; separate DNA or polypeptides using electrophoresis);

– describe the major findings that have arisen from the Human Genome Project (e.g., create a timeline of the project, or make a chart of the discoveries).

Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

– explain the roles of evidence, theories, and paradigms in the development of scientific knowledge about genetics (e.g., explain the impact of cloning a sheep on the theory of differentiation; explain the impact of the discovery of the structure of DNA as the universal molecule for living organisms);

– describe the principal elements of the Canadian regulations on biotechnological products, and explain their implications (e.g., consult Environment Canada or Food and Health Canada for the regulations; or use current websites for agencies such as Agriculture Canada that list new products).

Homeostasis

Overall Expectations

By the end of this course, students will:

- describe and explain the physiological and biochemical mechanisms involved in the maintenance of homeostasis;
- analyse, through experiments and the use of models, the feedback mechanisms that maintain chemical and physical homeostasis in animal systems;
- analyse how environmental factors (physical, chemical, emotional, and microbial) and technological applications affect/contribute to the maintenance of homeostasis, and examine related societal issues.

Specific Expectations

Understanding Basic Concepts

By the end of this course, students will:

- describe the anatomy and physiology of the endocrine and nervous systems, and explain their roles in homeostasis;
- explain the action of hormones in the female and male reproductive systems, including the feedback mechanisms involved;
- explain the role of the kidney in maintaining water and ion balance;
- describe and explain homeostatic processes involved in maintaining water, ionic, thermal, and acid-base equilibria in response to both a changing environment and medical treatments (e.g., explain the feedback mechanisms involved in water balance or thermo-regulation; explain the buffering system of blood; describe the effect of disorders of the nervous system or endocrine system; describe how chemotherapy affects homeostasis);
- describe the mammalian immunological response to a viral or bacterial infection;
- predict the impact of environmental factors such as allergens on homeostasis within an organism.

Developing Skills of Inquiry and Communication

By the end of this course, students will:

- construct a model that illustrates the essential components of the homeostatic process (e.g., use a flow chart to describe representative feedback mechanisms in living things);
- design and carry out an experiment to investigate a feedback system (e.g., record physiological effects of drinking coffee);
- design and conduct an experiment using invertebrates to study the response to external stimuli (e.g., instinctive behaviour in response to chemical stimuli or light);
- compile and display, either by hand or computer, data and information about homeostatic phenomena in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots (e.g., create a chart of hormones showing the source, stimulation, target organ, action and nature, and related disorders for each; make a graph of the reaction time of the pupil of the eye when stimulated by light of different colours; create a chart of allergies and the foods that trigger them).

Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

- synthesize case study information about the effects of taking chemical substances to enhance performance or improve health (e.g., explain the effect of steroids on health; debate the wisdom of taking large quantities of vitamins or amino acids; describe substances people use to cope with stress);
- present informed opinions about problems related to the health industry, health legislation, and personal health (e.g., describe issues related to transplants or kidney dialysis; discuss the difficulties in treating neurological and infectious diseases);
- describe some Canadian contributions to knowledge and technology in the field of homeostasis (e.g., the discovery of a new blood stem cell; the discovery of insulin).

Evolution

Overall Expectations

By the end of this course, students will:

- analyse evolutionary mechanisms, and the processes and products of evolution;
- evaluate the scientific evidence that supports the theory of evolution;
- analyse how the science of evolution can be related to current areas of biological study, and how technological development has extended or modified knowledge in the field of evolution.

Specific Expectations

Understanding Basic Concepts

By the end of this course, students will:

– define the concept of speciation and explain the mechanisms of speciation;

– describe, and put in historical and cultural context, some scientists' contributions that have changed evolutionary concepts (e.g., describe the contributions – and the prevailing beliefs of their time – of Lyell, Malthus, Lamarck, Darwin, and Gould and Eldridge);

– analyse evolutionary mechanisms (e.g., natural selection, sexual selection, genetic variation, genetic drift, artificial selection, biotechnology) and their effects on biodiversity and extinction (e.g., describe examples that illustrate current theories of evolution, such as the darkening over time, in polluted areas, of the pigment of the peppered moth, an example of industrial melanism);

– explain, using examples, the process of adaptation of individual organisms to their environment (e.g., explain the significance of a short life cycle in the development of antibiotic-resistant bacteria populations).

Developing Skills of Inquiry and Communication

By the end of this course, students will:

– outline evidence and arguments pertaining to the origin, development, and diversity of living organisms on Earth (e.g., evaluate current evidence that supports the theory of evolution and that feeds the debate on gradualism and punctuated equilibrium);

– identify questions to investigate that arise from concepts of evolution and diversity (e.g., Why do micro-organisms evolve so quickly? What factors have contributed to the dilemma that pharmaceutical companies face in trying to develop new antibiotics because so many micro-organisms are resistant to existing antibiotics?);

– solve problems related to evolution using the Hardy-Weinberg equation;

– develop and use appropriate sampling procedures to conduct investigations into questions related to evolution (e.g., to determine the incidence of various hereditary characteristics in a given population), and record data and information;

– formulate and weigh hypotheses that reflect the various perspectives that have influenced the development of the theory of evolution (e.g., apply different theoretical models for interpreting evidence).

Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

– relate present-day research and theories on the mechanisms of evolution to current ideas in molecular genetics (e.g., relate current thinking about adaptations to ideas about genetic mutations);
– describe and analyse examples of technology that have extended or modified the scientific understanding of evolution (e.g., the contribution of radiometric dating to the palaeontological analysis of fossils).

Population Dynamics

Overall Expectations

By the end of this course, students will:

- analyse the components of population growth, and explain the factors that affect the growth of various populations of species;
- investigate, analyse, and evaluate populations, their interrelationships within ecosystems, and their effect on the sustainability of life on this planet;
- evaluate the carrying capacity of the Earth, and relate the carrying capacity to the growth of populations, their consumption of natural resources, and advances in technology.

Specific Expectations

Understanding Basic Concepts

By the end of this course, students will:

- explain the concepts of interaction (e.g., competition, predation, defence mechanisms, symbiotic relationships, parasitic relationships) among different species of animals and plants;
- describe characteristics of a population, such as growth, density, distribution, carrying capacity, minimum/viable size;
- compare and explain the fluctuation of a population of a species of plant, wild animal, and micro-organism, with an emphasis on such factors as carrying capacity, fecundity, and predation;
- use examples of the energy pyramid to explain production, distribution, and use of food resources;
- explain the demographic changes observed over the past ten thousand years (e.g., explain the effect on populations of such factors as epidemics, the rise of agriculture, the Industrial Revolution, and the development of modern medicine);
- explain, using demographic principles, problems related to the rapid growth of human populations and the effects of that growth on future generations (e.g., relate the carrying capacity of the Earth to the growth of populations and their consumption of resources).

Developing Skills of Inquiry and Communication

By the end of this course, students will:

- use conceptual and mathematical models to determine the growth of populations of various species in an ecosystem (e.g., use the concepts of exponential, sigmoid, and sinusoidal growth to describe and predict various populations);
- determine experimentally the characteristics of population growth of two populations (e.g., examine the population cycles of a predator and a prey, or those of two populations that compete for food);
- using the ecological hierarchy for living things, evaluate how a change in one population can affect the entire hierarchy both physically and economically (e.g., the effects of the killing off of species of fish by lamprey eels, or the results of the introduction of zebra mussels into the Great Lakes);
- investigate, individually or collaboratively, the effects of human population growth on the environment and the quality of life (e.g., effects on ecosystems, such as the elimination of wildlife, plants, and farmland; causes and effects of ozone depletion or acid rain).

Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

– analyse Canadian investments in human resources and agricultural technology in a developing country (e.g., investigate Canadian International Development Agency [CIDA]-funded projects in a developing country);

– describe examples of stable food-production technologies that nourish a dense and expanding population;

– outline the advances in medical care and technology that have contributed to an increase in life expectancy, and relate these developments to demographic issues.