Catholic District School Board Writing Partnership

Science

Course Profile

Biology

Grade 12
University Preparation
SBI4U

- *for teachers by teachers*

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Course Overview
Biology, SBI4U, Grade 12, University Preparation

Policy Document: *The Ontario Curriculum, Grades 11 and 12, Science, 2000.*
Prerequisite: SBI3U

Course Description

This course provides students with an in-depth study of biological processes. Students study metabolic processes, evolution, molecular genetics, homeostasis, and population dynamics. The course focuses on the theoretical aspects of the topics under study. Students further develop their investigatory skills through researching, designing and conducting experiments. In addition, students link concepts studied to technological applications. Through the achievement of detailed knowledge and skills, students are prepared for further study in various branches of life sciences and related fields.

How This Course Supports the Ontario Catholic School Graduate Expectations

This course profile integrates relevant Catholic beliefs, values and Church teachings within the overall context of the knowledge and skills being addressed. While each unit has an integrity and autonomy of its own, there are also identifiable themes that bridge each of the units and connect them in a holistic way. A crucial theme in the course is the theory of evolution. As such, it provides a framework around which knowledge, skills and values are organized. Catholic beliefs, values and teachings related to this theme include: God as Creator, God's Providence, and the value and dignity of the human person. While the aforementioned are pervasive throughout the profile, there are also values, teachings and beliefs particular to each unit. The homeostasis unit raises issues about the value of human life, the sacredness of the body and the conjugal act, and the accessibility and marketing of health care. The molecular genetics unit also raises the question of stewardship of the environment. The population dynamics unit includes values related to the common good. In addition to addressing specific issues raised in the course, this profile further contributes to the development of the Ontario Catholic Graduate by developing his/her skills of discernment, reflection, communication, analysis, collaboration and self-direction.

Course Notes

University preparation courses are designed to equip students with the knowledge and skills they need to meet the entrance requirements for university programs. This course provides students with the prerequisite knowledge and skills needed for further study in life sciences and related fields. In planning for this course, teachers must be aware of and emphasize the theoretical aspects of the course content. Teachers should emphasize the development and demonstration of both independent research and learning skills. Teachers must incorporate the skills essential for scientific investigation that apply to all areas of the course content and as such must be developed in all the course units. In this profile, these skills expectations have been coded as Scientific Investigation Skills (SIS.01 to SIS.10).

This course is organized into five units to follow the logical development of knowledge, theories and skills. The units are Metabolic Processes, Molecular Genetics, Evolution, Homeostasis, and Population Dynamics.

Teachers may wish to integrate the strands into units following a different arrangement than that suggested in this course profile e.g., population dynamics could be done before homeostasis, but in doing so they must consider the time allocated to each.

The teacher must provide ample opportunities for students to engage in safe, relevant laboratory activities in all units of this course. The health and safety of teachers and students must be routinely addressed when conducting laboratory activities as outlined in Workplace Hazardous Materials Information System (WHMIS) legislation. Teachers need to take precautionary measures to ensure that students with food allergies are not placed at risk. They should discuss this issue with students and follow safe practices outlined in school and board policy.

It is suggested that students keep a journal for the course in which they record questions and reflections that arise as a result of issues raised throughout the course, in this profile this journal is called the Journeyer's Journal. Students could divide the pages in their Journeyer's Journal in half vertically. One side of the page could be devoted to moral/ethical reflections and questions while on the other side they could formulate and write out their questions, hypotheses and thoughts on scientific ideas and concepts that arise throughout this unit. By suggesting a split page, students and teachers alike can visually track their ideas and questions. In specific units, such as the evolution unit, teachers can assess students' scientific questions using an appropriate assessment tool. As a reflective document, the Journeyer's Journal will not be formally assessed; however, the teacher may choose to include in it items that could be assessed e.g., refer to Unit 3.

Starting with the study of metabolic processes, students learn the basic chemical concepts necessary for the understanding of biological processes. Molecular genetics includes the study of genes and their expression, and its implication for genetic continuity. Darwinian evolution provides the theoretical framework for aligning concepts studied in subsequent units. Homeostasis connects the biochemical to the physical/physiological mechanisms relating to human health. The course ends with a discussion of population dynamics that connects students back to earlier science courses.

Students are expected to use computer technology. Teachers are encouraged to incorporate the use of tools such as computer-based simulations and multimedia applications. Science cannot be taught in isolation but must be linked to other disciplines. By understanding connections and interdependence, students develop an awareness of controversial issues involving science, technology, society and the environment (STSE). This enables them to become reflective and critical thinkers who examine, evaluate, and apply knowledge of interdependent systems for the development of a just and compassionate society.

Units: Titles and Time

Unit 1	Metabolic Processes	24 hours
Unit 2	Molecular Genetics	23 hours
* Unit 3	Evolution	20 hours
Unit 4	Homeostasis	23 hours
Unit 5	Population Dynamics	20 hours

* This unit is fully developed within this Course Profile.

Unit 1: Metabolic Processes

Time: 24 hours

Unit Description

This unit builds on the Grade 11 University Preparation Biology course expectations in the Cellular Functions unit. After reviewing how cells are structured, students study cell functioning at a molecular level. Students move from simple to complex concepts as they continue to investigate the cell and its processes, specifically metabolism. Students investigate the macromolecules that comprise the cell and progress to the importance of metabolism in the cell, the laws which govern energy use in metabolism, and an investigation into two important metabolic processes, photosynthesis and cellular respiration. Finally, students explore the importance of metabolism in their everyday lives and in technological developments.

In Activity 1, students reflect on the origin of life in their Journeyer's Journal. A brief discussion of how living things came to be on our planet introduces students to the building blocks of cells, which are the basis of all living things. A diagnostic assessment reviews concepts of macromolecules and cell processes studied in Grade 11, followed by a general review of the structure of cells (Singer-Nicolson cell membrane model, nuclear pores, mitochondria, etc.). Students review and continue to discover the different functional groups found in important macromolecules using computer simulations, and study their impact on the properties of those molecules, and the types of chemical reactions that produce these macromolecules. Students identify the relationship between macromolecular structure and metabolism through case study analysis.

In the second activity, students explore metabolism, its role, its requirements, and the laws that govern it. Students reflect on the transformation of energy that occurs in everyday situations, and apply the laws of thermodynamics to explain these transformations. Students create a scientific glossary of important terms used in the study of metabolism. Students discover the role of enzymes in metabolism, and use this information to design and perform an investigation into the factors that affect enzymatic activity. Following this, students conduct research on a technological application of enzyme activity in the food and pharmaceutical industries, and present their findings as an editorial.

In the third activity, students apply their knowledge of metabolism in a detailed way to the two important metabolic processes of photosynthesis and cellular respiration. Through laboratory investigations, and the use of micrographs and laboratory data, students compare photosynthesis and cellular respiration, with respect to their pathways, enzymes, reactants, products, and conditions. Students also examine the role of other biologically important molecules in these processes.

In the fourth activity, students choose a topic that demonstrates the relevance of the study of cell biology and/or cell-related technologies to everyday life and create a poster that illustrates this relationship.

Unit Overview Chart

Cluster	Learning Expectations	Assessment Categories	Focus
1	MPV.01, MP1.02, 1.04, MP2.02, 2.03 CGE 2b, 2e, 4f SIS.04, .02	Knowledge Communication Inquiry	Cell structure and processes - Structure and function of biological molecules and functional groups - Biochemical reactions - Relationship between molecules and metabolism
2	MPV.01, MP1.03, MP2.01, 2.04, MP3.01, 3.02 CGE 2b, 2d, 5a SIS.01, .03, .05, .07	Knowledge Communication Inquiry Making Connections	Energy and Metabolism - Metabolic terms defined - The laws of thermodynamics - Structure and function of enzymes - Applications of enzymes
3	MPV.02, MP1.01, 1.05, 1.06, MP2.05, 2.06 CGE 2b, 2d, 5a SIS.01, .03, .05, .07	Knowledge Inquiry Communication	Photosynthesis and Cellular Respiration - The laws of thermodynamics applied - Reactants - Products - Pathways - Energy flow - Cell components (mitochondria, chloroplast)

4	MPV.03, MP3.03 CGE 2b, 2d SIS.05	Communication Making Connections	Societal Impact of Metabolism and Cell Biology
5		Knowledge Communication	Unit Test

Unit 2: Molecular Genetics

Time: 23 hours

Unit Description

This unit is divided into three activities that work in a developmental order from simple structural and functional concepts to more complex process-related concepts and finally to an analysis of the societal impact of biotechnology. This unit builds on the knowledge and skills in the Genetic Continuity unit from the Grade 11 University Preparation Biology course.

In the first activity, students manipulate models of RNA and DNA in order to gain a conceptual understanding of the differences between the two and the process of DNA replication. Teachers are encouraged to use both computer-based models and molecular models for students to gain as complete a conceptual understanding as possible. Students investigate the genetic composition of cells by extracting DNA from plant crops such as wheat germ.

In the second activity, students study the steps involved in protein synthesis through examining the process as depicted in text, video, and electron photomicrographs, then synthesizing the information into a two-dimensional illustration of the process. Students study the causes and effects of mutations. They analyse the effects of mutations on variations in the genetic code of cytochrome c among different species of organisms. The introduction of the cytochrome c molecule here connects to a suggested case study in the Evolution unit.

In the third activity students create a pamphlet (one piece of 8" × 10" paper folded into six panels) summarizing the history of the Human Genome project, including the process of sequencing DNA bases. Students create a graphic organizer that summarizes the contributions of genetic engineers, molecular biologists and biochemists to the field of genetics. In their Journeyer's Journal, students consider, as Catholics, how modern genetics and its related technologies may open a Pandora's box and pose serious ethical dilemmas for society. Students write a position paper on whether they consider Health Canada's food safety assessment process for genetically modified (GM) foods to be sufficiently rigorous.

Unit Overview Chart

Cluster	Learning Expectations	Assessment Categories	Focus
1	MGV.01, .02, MG1.01, 1.02, 2.03 CGE 2b SIS.01, .02, .03, .04, .06, .07	Knowledge Inquiry	RNA and DNA - Structure, and function, and comparison of RNA and DNA - DNA replication
2	MGV.01, .02, MG1.03, 1.04, 2.01, 2.02. CGE 2b SIS.05	Knowledge Inquiry Communication	Protein Synthesis - Steps - Mutations - Regulation of protein synthesis

3	MGV.03, MG1.05, 1.06, 1.07, 2.04, 3.01, 3.02 CGE 2b, c, d, 7d SIS.05, .06	Knowledge Communications Making Connections	Molecular Genetics and Societal Impact - Pamphlet on the human genome project and sequencing bases - Graphic organizer outlining the contributions of genetic engineers, molecular biologists and biochemists to the field of genetics - Position paper on the rigor of Health Canada's food safety assessment process for GM foods
4		Knowledge Communications	Unit Test

Unit 3: Evolution

Time: 20 hours

Unit Description

In this unit students investigate Darwin's theory of evolution, its development, evidence that supports it, and mechanisms that explain it. Students identify questions that arise from concepts of evolution and diversity, solve problems using the Hardy-Weinberg equation and conduct investigations relating to evolution. This unit builds on concepts introduced in the Diversity, Genetic Continuity, and Cellular Functions units from the Grade 11 University Preparation Biology course and from the first two units of this course. Evolution is presented to students within a Catholic context, which views reality through the eyes of faith and challenges students to grow in a fuller understanding of their faith. Appendix 5: The Serpent and the Soul (A Catholic Perspective on Bioethical Issues) is a useful resource and reflection. In this unit students could divide the pages in their Journeyer's Journal vertically in half. Students could devote one side of the page to moral/ethical reflections and questions, while on the other side formulating and writing out their questions, hypotheses, and thoughts on scientific ideas and concepts that arise throughout this unit. With a split page, students and teachers can visually track their ideas and questions.

In the first activity, an introduction to the historical and cultural context of evolution occurs using various sources, including the Scopes Trial (excerpts from the novel or video could be used). Students participate in a small group activity in which they explore the culture, history, and development of evolutionary theory by analysing a variety of items selected. Students then research the work of individuals or events, and make a conceptual timeline of their contribution to evolution. In their Journeyer's Journal students identify questions relating to the theological, ethical, and conceptual issues of evolution and diversity.

In the second activity, students learn about the critical role that evidence plays in the development of a theory. Using their timeline from Activity One, they identify different examples of evidence that have influenced the development of the theory of evolution. Using a case study or other inquiry activity students analyse the ability of one or more types of evidence to support a hypothesis that explains the theory of evolution, communicating their results in a discussion paper. Examples of how advances in technology have increased our understanding of evolution are described and analysed.

In the third activity, students use a model to simulate the Hardy-Weinberg principle. Students develop and use sampling procedures to gather data based on simulations of the peppered moth studies. Using their results, students explain the process of adaptation of organisms to their environment.

In Activity Four, students study the mechanisms associated with speciation (microevolution, reproductive isolation, and geographical mechanisms) and apply those mechanisms to explain speciation in Darwin's finches.

In Activity Five, students investigate the mechanisms of the evolution of a specific molecule, cytochrome c, by means of current research in molecular genetics.

It is recommended that the teacher give a summative test, and this is indicated as Activity Six in the Overview Chart. This test should be rigorous and reflective of the depth of knowledge required in this unit.

Unit Overview Chart

Cluster	Learning Expectations	Assessment Categories	Focus
1	EVV.02, .03, EV1.02, EV2.02 CGE 1h, 1i, 2e, 3c, 5a, 5e, 5f SIS.05, .06	Knowledge Communication Making Connections	Theory of Evolution - Historical study - Diversity and evolution
2	EVV.02, .03, EV2.01, 2.02, 2.05, EV3.02 SIS.05, .10 CGE 2d, 3c	Inquiry Communication	Evidence of Evolution - Perspectives on evolution - Role of technology
3	EVV.01, EV1.03, EV2.03, 2.04 SIS.05, .06, .07 CGE 3c, 5a	Knowledge Inquiry	Evolutionary Mechanisms - Mechanisms of microevolution - Hardy-Weinberg equation - Adaptation
4	EVV.01, EV1.01, 1.03, 1.04 CGE 3c, 5a SIS.05	Knowledge	Speciation - Mechanisms of speciation - Darwin's finches
5	EVV.03, EV3.01 CGE 3c SIS.05	Making Connections	Modern Molecular Evidence - Cytochrome c research
6		Knowledge Communication	Unit Test

Unit 4: Homeostasis

Time: 23 hours

Unit Description

In this unit, students study the concept of homeostasis through an exploration of the anatomy and physiology of the endocrine and nervous systems, the immune response, and Canadian contributions to the field of stem cell research. Students progress from examining simple homeostatic mechanisms to examining the structure and function of systems involved in the coordination of the homeostatic response. Each activity incorporates either an inquiry or research component that reinforces and enhances students' understanding of the concepts studied.

In the first activity, students are introduced to the work of Claude Bernard, and study various homeostatic mechanisms involved in osmoregulation, thermoregulation, and acid/base equilibria. Students construct a simple model to demonstrate a feedback loop, e.g., temperature, blood glucose, water balance. An inquiry approach is used to study both the role of the kidney in osmoregulation and thermoregulatory responses, to heat production through exercise.

In the second activity, students study the structure and function of the endocrine system with an emphasis on the male and female reproductive systems. Students collect data on the major endocrine glands and compile a chart that summarizes information related to the glands, hormones produced, chemical structure effects and regulation of their action, morphology, and cell structure/function relations.

Students research the effects of chemical substances that mimic endocrine hormones on individuals' health and/or performance.

In the third activity, students study the structure and function of the nervous system as it relates to homeostasis. Students design and carry out an investigation on the response of organisms such as the earthworm or *Planaria* to light as a stimulus. Students reflect and form opinions on the biological, economic, scientific, political and social difficulties that must be overcome in the treatment of neurological disease in their Journeyer's Journal. A movie or book based on a real-life situation forms the context for reflection, and students form opinions on the basis of further research into diseases such as adrenoleukodystrophy.

In the fourth activity, students study the immune response from a homeostatic perspective. Students examine the mammalian response to pathogenic bacteria (e.g., *E.coli, Anthrax*) and viruses (e.g., AIDS). Students examine and predict the impact of environmental factors such as allergens on homeostasis. Students research Canadian contributions to stem cell research as it relates to homeostatic processes, (e.g., Allison Blair, John Dick, Guillermo Guenechea, Olga Gan, Craig Dorrell). After defining what a stem cell is, students analyse the ethics of stem cell research from a Catholic perspective. Students create a newspaper called *The Catholic Times* (the issue is dedicated to stem cell research in Canada). Students include articles on Canadian stem cell research, as well as an editorial that comments on the ethical issues related to stem cell research and the Catholic Church's position on the research. Students reflect on the articles in their Journeyer's Journal.

Unit Overview Chart

Cluster	Learning Expectation	Assessment Categories	Focus
1	HSV.01, .02, HS1.03, 1.04, HS2.01, 2.02 CGE 3c; 4f; 5a SIS.03, .04, .05, .06	Knowledge Inquiry Communication	Homeostatic Mechanisms - Osmoregulation, thermoregulation and acid/base equilibria - Role of the kidney - Feedback mechanisms/loops - Students reflect on the ethical issues around dialysis and kidney transplants, and record their thoughts in their journals (i.e., Who has access? Who bears the cost? Who gets the kidney?).
2	HSV.01, .03, HS1.01, 1.02, 2.04, 3.01 CGE 3c, 3e, 7d SIS.06	Knowledge Communication Making Connections	Endocrine System - Anatomy and physiology - Role of hormones in reproductive systems - Effects of chemical substances on the health or performance of the person - Students reflect on the ethical issues around hormonal regulation of the female reproductive cycle and record their thoughts in their journals.
3	HSV.02, .03, HS1.01, 2.03, 2.04, 3.02 CGE 2a, 2c, 3d, 3f, 7d, 7e SIS.01, .02, .03, .04, .05, .06, .07	Knowledge Inquiry Communication Making Connections	Nervous System - Anatomy and physiology - Stimulus and response - Neurological disease - Students reflect on the ethical issues around suffering, death and euthanasia and record their thoughts in their journals.

4	HSV.03, HS1.05, 1.06, HS3.03 CGE 2a, 3a, 7d SIS.05	Knowledge Making Connections Communication	Immune Response - Response to bacterial and viral infections - Immune disorders - Allergens and immune response - Students research and record Canadian contributions to stem cell research and the associated ethical issues and publish them in a newspaper called The Catholic Times.
5		Knowledge Communication	Unit Test

Unit 5: Population Dynamics

Time: 20 hours

Unit Description

In this unit, students build on the ecological principles learned in the Grade 10 academic science course as they investigate the field of population dynamics in ecology. Students explore characteristics and models of population growth, as well as the factors that affect it, and apply this knowledge to animal, plant, microorganism, and human populations. While assessing the population growth of humans, students examine the reasons for this growth pattern and its implications. The unit concludes with a general look at the production, distribution and use of food resources, and a special investigation into the problem and solutions of feeding our dense and expanding population, especially in developing countries.

The first activity introduces students to basic principles of demography, including population growth, distribution, and density, and students apply these concepts to a particular species. Through analysis of various population growth patterns, students discover the different models of population growth, and the concept of carrying capacity. Using the knowledge gained thus far, students apply these concepts to the growth patterns of plants, animals, and microorganisms, and compare and explain the fluctuations of the populations.

In Activity 2, students move from the study of populations to the study of communities. Students participate in a jigsaw activity to discover the interactions that affect the population growth of a species and the impact that the population growth of one species has on that of another species. Through simulation activities and experimentation, students explore the cyclic changes in population size that characterize predator and prey interactions. As a follow-up to this activity, students analyse and critique an article that illustrates a Canadian example of one of the relationships discussed in class. Teachers are encouraged to use examples where humans are removed from the equation to allow students to see if and how the populations of both predator and prey recover. Students reflect in their Journeyer's Journal about why humans cannot hope to control any environment, and so why it is better for humans to work with nature than against it.

In Activity 3, students use the knowledge gained in the first two activities to analyse human population growth over the past ten thousand years. In small groups, students hypothesize reasons for this growth pattern as well as its implications, both present and future, and then present their ideas and knowledge in the form of a concept map. Students examine the factors that have contributed to our rapid population growth in terms of health care and life expectancy and the technological advances that are responsible for these changes. They summarize the milestone achievements in the form of a timeline, highlighting key Canadian contributions.

In Activity 4, students continue to examine the implications of our human population growth pattern, with a specific focus on food supply. Students begin with a brief introduction to the production, distribution, and use of food resources, and then examine these dimensions in various countries, including developing countries. Students choose a developing country to investigate with respect to these issues, and present their research in the form of a report evaluating the situation in this country. Students reflect on their findings in their Journeyer's Journal.

Unit Overview Chart

Cluster	Learning Expectations	Assessment Categories	Focus
1	PDV.01, PD1.02, 1.03, PD2.01 CGE 2b, 2c, 2d, 7b SIS.04, .06	Knowledge Communication Inquiry	Population Demographics - Characteristics - Models of population growth - Fluctuations
2	PDV.02, PD1.01, PD2.02, 2.03 CGE 2b, 2d SIS.04, .05, .06, .07, .08, .09	Knowledge Communication Inquiry	Community Interactions - Types - Population cycles - Population interactions
3	PDV.03, PD1.05, 1.06, PD2.04, PD3.03 CGE 2b, 2d, 3c, 4f SIS.05, .06	Knowledge Communication Inquiry Making Connections	Human Population Demographics - Patterns and problems of human population growth - Implications and consequences on quality of life - Advances in medicine and technology
4	PDV.03, PD1.04, 1.06, PD3.01, 3.02 CGE 1d, 2b, 2c, 2d, 2e, 3c, 7i SIS.05, .06	Knowledge Communication Making Connections	The effect of Rapid Population Growth on Resources and Future Generations - Energy pyramids - Food production and technology - Canadian contributions
5		Knowledge Communication	Unit Test

Teaching/Learning Strategies

When planning this course, the teacher should consider both the course expectations and the needs of individual students. The teacher should provide learning experiences that promote interest, understanding, and excellence. To prepare students to meet the university entrance requirements, the teacher must deliver the full provincial curriculum, emphasizing the theoretical aspects of the course, and incorporating relevant applications. It is suggested that diagnostic assessments be used to help determine the level of students' prior knowledge before beginning each unit. Teachers may need to be more Socratic in their approach to ensure coverage of the expectations as required in a university destination course. The teacher's role is to establish the conceptual framework to help the students develop specific skills and attitudes while considering the individual student's learning style. By fostering an atmosphere where learning is meaningful, integrative, challenging, active, and value-based, the teacher can help students become excited about learning.

Throughout this course students should have the opportunity to acquire knowledge and develop skills and attitudes through a variety of teaching and learning strategies. The strategies used should provide students with multiple opportunities to develop and demonstrate their learning and skills across all four categories of the Achievement Chart. The following is a list of suggestions with examples of links to the course expectations.

Expectations that require knowledge can be developed through:

- brainstorming (PD1.01);
- teacher-directed lessons and discussions (MP1.02, MP1.05, MG1.03, EV1.02);
- small group instruction;
- independent research (MG1.04, MG1.07);
- self-directed learning.

Expectations that involve inquiry can be met by:

- conducting and analysing experiments (PD2.02);
- designing lab investigations (EV2.04, MP2.04, HS2.02);
- interpreting micrographs (MG2.02, MP2.05);
- formulating questions (HS2.01);
- building models (MP2.02);
- solving problems (EV2.03, MP2.03).

Expectations that encourage communication can be demonstrated by:

- written reports;
- essays;
- discussion papers (EV2.01);
- group discussions (EV1.01);
- debates (HS3.02);
- seminars;
- student presentations (for example, oral presentations, multimedia presentations, video and audio presentations, skits, photo essays etc.) (HS2.04).

Expectations where students expand their knowledge to make connections can be developed through:

- independent research (PD3.01);
- exposure to experts in their field (for example, by attending university lectures or doing Internet research);
- reflective papers;
- case studies;
- portfolios;
- participation in science fairs;
- article critique (MG3.02).

Assessment and Evaluation of Student Achievement

The primary purpose of assessment and evaluation is to improve student learning. Information gathered through assessment helps the teacher determine students' strengths and weaknesses in their achievement of the course expectations.

To allow students to demonstrate that they have mastered the expectations, the teacher must establish a balanced assessment plan for the course and select appropriate methods, strategies and tools. Students must demonstrate that they have developed both independent research skills and independent learning skills. Assessment and evaluation must be based on the curriculum expectations for this course and the achievement levels outlined in the *Program Planning and Assessment, 2000* document. When this course was designed, the learning expectations were clustered in order to balance the categories within the Achievement Chart.

At the beginning and throughout the course, the teacher must share the assessment criteria with the students and their parents/guardians, and give feedback that guides students' efforts towards improvement. The assessment results should be used to motivate students and help them establish the next steps in their learning goals. In order to ensure that assessment and evaluations are valid and reliable the teacher must use assessment and evaluation strategies that:

- address both what the students learn and how well they learn it;
- are based on both the categories of knowledge and skills and on the achievement levels;
- are varied in nature, administered over a period of time, and demonstrate the full range of their learning;
- promote the students' ability to assess their own learning and to set specific goals.

Assessment practices must provide teachers with information on what students know and can do throughout this course.

The corresponding methods of assessment are:

- paper-and-pencil task;
- personal communication task;
- performance tasks.

Possible assessment strategies include:

- paper-and-pencil task: tests, quizzes, concept maps, essay, written report/lab reports, research paper;
- personal communication tasks: interviews, conferences, journals, and classroom discussions;
- performance task: individual presentations, plays/skits, and lab performance.

The tools used to effectively measure the students' learning and mastery of skills are as follows:

- checklists;
- marking schemes;
- rating scales;
- rubrics.

As this is a university preparation course, we recommend that teachers carefully consider a balanced weighting of the four categories of achievement throughout each unit and in the final evaluation. This will ensure that students have ample opportunity to develop and demonstrate their level of achievement of the knowledge, independent research, and learning skills for this university preparation course. Knowledge could be assessed through multiple choice type questions, inquiry through a lab practicum or dry lab question, and/or making connections through an extended response, short essay type question, or critique of a journal article. Seventy per cent of the grade will be based on assessments and evaluations conducted throughout the course. This portion of the grade should reflect the students' most consistent level of achievement throughout the course, although special consideration should be given to the more recent evidence of achievement. It is recommended that teachers use summative tests to determine student achievement for each unit of study in this course. Thirty per cent of the grade will be based on a final evaluation. Performance tasks, an essay, and/or other methods of evaluation may be incorporated into the final evaluation.

Teachers may choose to encourage students to design and conduct a Science Fair project, which would allow them to further develop their independent research and learning skills. If this is to be used as part of the summative evaluation for this course, care should be taken to ensure that expectations from several units are incorporated.

Accommodations

Students should be given every opportunity to achieve the expectations for this course wherever possible. Teachers must consider the needs of exceptional students when planning the science curriculum. Accommodation to the program activities and/or the environment may be necessary. Teachers should consult individual students' Individual Education Plan (IEP) for specific direction on accommodation. Where the student has an IEP, the teacher must meet the needs of the student as outlined in the Plan.

Exceptional students, as well as other students who are not identified as exceptional but who have an IEP and are receiving special education programs and services, should be given every opportunity to achieve the curriculum expectations set out for this course. A variety of teaching approaches may need to be used to help exceptional students achieve the learning expectations of this course. Examples of such approaches may include:

- using a variety of teaching/learning strategies (e.g., special interest groupings for research projects, collaborative groups, mentorship programs, independent study plans);
- collaborating with resource teachers, teacher-librarians, and other professionals;
- allowing more time for the completion of assignments or achievement of the learning expectations;
- providing alternative ways of completing tasks or presenting information (e.g., taped answers);
- providing alternative homework assignments;
- providing alternative tasks for highly-motivated and gifted students (e.g., participation in district science fairs, subject-specific university-based competitions, attendance at university-sponsored activities/lectures).

Assessment procedures and strategies may also need to be altered. Examples include:

- changing the time requirement of assignments or assessment tasks;
- changing the format of the assessment material (e.g., Braille);
- simplifying test instructions and the language of questions;
- allowing the use of scribes, tape recorders, word processors etc.

For English As a Second Language (ESL) students or English Literacy Development (ELD) students, teachers should provide opportunities for the students to demonstrate their learning by alternate means such as: pairing written instructions with verbal instructions; using key visuals to illustrate definitions; allowing extra time for reading or written assignments; using first-language dictionaries for assignments.

For students with physical or learning impairments, classroom and laboratory activities should be altered to permit maximum participation. If possible, students with physical disabilities should be allowed access to sinks, lab desks etc., that are appropriate to their needs.

Resources

The URLs for the websites were verified by the writers prior to publication. Given the frequency with which these designations change, teachers should always verify the websites prior to assigning them for student use. Units in this Course Profile make reference to the use of specific texts, magazines, films, videos and websites. Teachers need to consult their board policies regarding use of any copyrighted materials. Before reproducing materials for student use from printed publications, teachers need to ensure that their board has a Cancopy licence and that this licence covers the resource they wish to use. Before screening videos/films with their students, teachers need to ensure that their board/school has obtained the appropriate public performance videocassette licence from an authorized distributor. Teachers are reminded that much of the material on the Internet is protected by copyright. The copyright is usually owned by the person or organization that created the work. Reproduction of any work or substantial part of any work on the Internet is not allowed without the permission of the owner.

Print Materials

Catechism of the Catholic Church. Ottawa: Publication Service, Canadian Conference of Catholic Bishops, 1994. ISBN 0-88997-281-8

Challenge and A Responsibility. *AIDS: A Catholic Educational Approach to HIV*. Toronto: OCCB, 1999.

Celebrating An Education for Justice and Peace. The Catholic Bishops of Ontario. Toronto: OCCB, 1996.

Bowers, Ray, et al. *Biology 11*. Toronto: Pearson Education Canada, 2002. ISBN 0-201-70802-7

Galbraith, Don, et al. *Biology 11*. Toronto: McGraw-Hill Ryerson, 2001. ISBN 0-07-088708-X

Galbraith, D., et al. *Understanding Biology*. Toronto: J. Wiley & Sons, 1989. ISBN 0-471-79654-9

Instruction on Respect for Human Life in Its Origin and the Dignity of Procreation. Vatican City: Vatican Press, 1987.

Lawrence, Jerome, and Robert E. Lee. *Inherit the Wind*. Bantam Books, 1950. ISBN 0553254359

Ritter, Bob, et al. *Nelson Biology 11*. Toronto: Nelson Thomson Learning, 2002. ISBN 0-17-612138-2

Suzuki, David. *Earth Times*. Toronto: Stoddart, 1998.

Suzuki, David. *The Sacred Balance*. Toronto: Greystone Books, 1997.

The New American Catholic Bible. Wichita, Kansas: Catholic Bible Publications, 1992.

Non-Print Materials

CD-ROM

"A.D.A.M." Fort Erie: Films for the Humanities and Sciences, 2000.

"Life Processes and Green Plants." Fort Erie: Films for the Humanities and Sciences, 2000.

"Genetics." Fort Erie: Films for the Humanities and Sciences, 2000.

"Human Health." Fort Erie: Films for the Humanities and Sciences, 2000.

"Humans as Organisms." Fort Erie: Films for the Humanities and Sciences, 2000.

Masterman, Dan. Biology with Computers Using Logger Pro. Portland: Vernier Software.

"Plant Biology Tutor." Fort Erie: Films for the Humanities and Sciences, 2000.

Videos

"AIDS: A Biological Perspective." Toronto: kineticvideo.com. 30 min.

"Alien Invaders: Biodiversity at Risk." Fort Erie: Films for the Humanities and Sciences, 2000. 30 min.

"Animated Neuroscience and the Action of Nicotine, Cocaine, and Marijuana in the Brain." Fort Erie: Films for the Humanities and Sciences, 2000. 25 min.

"Biotechnology." Fort Erie: Films for the Humanities and Sciences, 2000. 23 min.

"Genetic Discoveries, Disorders, and Mutations." Fort Erie: Films for the Humanities and Sciences, 2000. 26 min.

"Hand -Me-Down-Genes." Fort Erie: Films for the Humanities and Sciences, 2000. 2 part series: 28 min.

"Human Body 3." Toronto: National Geographic, 1998.

"Human Health." Toronto: kineticvideo.com

"Inherit the Wind." (feature film)

"Lorenzo's Oil." (feature film)

"Narcotics." Fort Erie: Films for the Humanities and Sciences, 2000. 30 min.

"Practical Applications and Risks of Genetic Science." Fort Erie: Films for the Humanities and Sciences, 2000. 24 min.

"Steroids." Fort Erie: Films for the Humanities and Sciences, 2000. 24 min.

"Surviving AIDS." NOVA, 1999. 60 min.

"The Global Impact of AIDS." Fort Erie: Films for the Humanities and Sciences, 2000. 50 min.

"The Jungle Pharmacy: Nature's Remedy." Fort Erie: Films for the Humanities and Sciences, 2000. 27 min.

"Understanding the Basic Concepts of Genetics." Fort Erie: Films for the Humanities and Sciences, 2000. 30 min.

"The World of Living Organisms." Fort Erie: Films for the Humanities and Sciences, 2000. 10 part series: 15 minutes each.

Websites

Scopes Trial: http://xroads.virginia.edu/- UG97/inherit/contents.html

OSS Considerations

Students can benefit from experiences in biology-related activities through Cooperative Education. They may consider a Cooperative Education placement related to this course. Students should explore biology/chemistry-related careers throughout the course and consider them when they are developing their Annual Education Plan (AEP). Student Services/Guidance is an excellent resource centre for career research, and most universities have websites that are easily accessible to all students.

Students may choose to job shadow; this gives them an opportunity to observe and gain a better understanding of biology related careers, for example in the area of health services and research.

Students should have a safe environment for learning free from harassment of all types, violence, and expressions of hate. Learning activities should be designed to help students develop respect for human rights and dignity, and to develop a sense of personal, social, and civic responsibility.

Students are required to complete 40 hours of community involvement activities prior to graduation. They should consult their Board's list of eligible Christian Service activities to complete this requirement.

Students graduating from Ontario schools are expected to be technologically literate. Through the study of this science course, students should be able to understand and apply technological concepts, to use computers in various applications, and to analyse the implications of technology on individuals and society.

Coded Expectations, Biology, Grade 12, University Preparation, SBI4U

Scientific Investigation Skills

SIS.01 - 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);

SIS.02 - 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);

SIS.03 - 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);

SIS.04 - 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);

SIS.05 - 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;

SIS.06 - 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);

SIS.07 - 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);

SIS.08 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;

SIS.09 - select and use appropriate SI units;

SIS.10 - 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

MPV.01 · 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;

MPV.02 · 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;

MPV.03 · 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

MP1.01 – apply the laws of thermodynamics to the transfer of energy in the cell, particularly with respect to respiration and photosynthesis;

MP1.02 – 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);

MP1.03 – 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);

MP1.04 – identify and describe the four main types of biochemical reactions: redox, hydrolysis, condensation, and neutralization;

MP1.05 – 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;

MP1.06 – 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

MP2.01 – 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*);

MP2.02 – 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);

MP2.03 – 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);

MP2.04 – 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);

MP2.05 – 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);

MP2.06 – 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

MP3.01 – relate knowledge gained from their current studies of metabolism to their learning in the fields of chemical thermodynamics and physical energy;

MP3.02 – 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);

MP3.03 – 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

MGV.01 · 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;

MGV.02 · explain, through laboratory activities and conceptual models, processes within the cell nucleus;

MGV.03 · 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

MG1.01 – compare the structure and function of RNA and DNA, and explain their roles in protein synthesis;

MG1.02 – describe the current model of DNA replication and methods of repair following an error;

MG1.03 – 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);

MG1.04 – 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);

MG1.05 – 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);

MG1.06 – describe the functions of the cell components used in genetic engineering (e.g., the roles of plasmids, restriction enzymes, recombinant DNA, and vectors);

MG1.07 – 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

MG2.01 – 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);

MG2.02 – interpret micrographs that demonstrate the cellular structures involved in protein synthesis;

MG2.03 – 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);

MG2.04 – 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

MG3.01 – 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);

MG3.02 – 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

HSV.01 · describe and explain the physiological and biochemical mechanisms involved in the maintenance of homeostasis;

HSV.02 · analyse, through experiments and the use of models, the feedback mechanisms that maintain chemical and physical homeostasis in animal systems;

HSV.03 · 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

HS1.01 – describe the anatomy and physiology of the endocrine and nervous systems, and explain their roles in homeostasis;

HS1.02 – explain the action of hormones in the female and male reproductive systems, including the feedback mechanisms involved;

HS1.03 – explain the role of the kidney in maintaining water and ion balance;

HS1.04 – 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);

HS1.05 – describe the mammalian immunological response to a viral or bacterial infection;

HS1.06 – predict the impact of environmental factors such as allergens on homeostasis within an organism.

Developing Skills of Inquiry and Communication

HS2.01 – 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);

HS2.02 – design and carry out an experiment to investigate a feedback system (e.g., record physiological effects of drinking coffee);

HS2.03 – 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);

HS2.04 – 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

HS3.01 – 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);

HS3.02 – 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);

HS3.03 – 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

EVV.01 · analyse evolutionary mechanisms, and the processes and products of evolution;

EVV.02 · evaluate the scientific evidence that supports the theory of evolution;

EVV.03 · 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

EV1.01 – define the concept of speciation and explain the mechanisms of speciation;

EV1.02 – 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);

EV1.03 – 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);

EV1.04 – 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

EV2.01 – 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);

EV2.02 – 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?);

EV2.03 – solve problems related to evolution using the Hardy-Weinberg equation;

EV2.04 – 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;

EV2.05 – 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

EV3.01 – 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);

EV3.02 – 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

PDV.01 · analyse the components of population growth, and explain the factors that affect the growth of various populations of species;

PDV.02 · investigate, analyse, and evaluate populations, their interrelationships within ecosystems, and their effect on the sustainability of life on this planet;

PDV.03 · 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

PD1.01 – explain the concepts of interaction (e.g., competition, predation, defence mechanisms, symbiotic relationships, parasitic relationships) among different species of animals and plants;

PD1.02 – describe characteristics of a population, such as growth, density, distribution, carrying capacity, minimum/viable size;

PD1.03 – 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;

PD1.04 – use examples of the energy pyramid to explain production, distribution, and use of food resources;

PD1.05 – 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);

PD1.06 – 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

PD2.01 – 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);

PD2.02 – 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);

PD2.03 – 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);

PD2.04 – 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

PD3.01 – 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);

PD3.02 – describe examples of stable food-production technologies that nourish a dense and expanding population;

PD3.03 – outline the advances in medical care and technology that have contributed to an increase in life expectancy, and relate these developments to demographic issues.

Ontario Catholic School Graduate Expectations

The graduate is expected to be:

A Discerning Believer Formed in the Catholic Faith Community who

CGE1a -illustrates a basic understanding of the **saving story** of our Christian faith;
CGE1b -participates in the **sacramental life** of the church and demonstrates an understanding of the centrality of the Eucharist to our Catholic story;
CGE1c -actively reflects on **God's Word** as communicated through the Hebrew and Christian scriptures;
CGE1d -develops attitudes and values founded on Catholic **social teaching** and acts to promote social responsibility, human solidarity and the common good;
CGE1e -speaks the **language of life**... "recognizing that life is an unearned gift and that a person entrusted with life does not own it but that one is called to protect and cherish it." (Witnesses to Faith)
CGE1f -seeks intimacy with God and celebrates **communion** with God, others and creation through prayer and worship;
CGE1g -understands that one's purpose or **call in life** comes from God and strives to discern and live out this call throughout life's journey;
CGE1h -respects the **faith traditions**, world religions and the life-journeys **of all people of good will**;
CGE1i -integrates faith with life;
CGE1j -recognizes that "sin, human weakness, conflict and forgiveness are part of the human journey" and that the cross, the ultimate sign of forgiveness is at the heart of **redemption**. (Witnesses to Faith)

An Effective Communicator who
CGE2a -listens actively and critically to understand and learn in light of gospel values;
CGE2b -reads, understands and uses written materials effectively;
CGE2c -presents information and ideas clearly and honestly and with sensitivity to others;
CGE2d -writes and speaks fluently one or both of Canada's official languages;
CGE2e -uses and integrates the Catholic faith tradition, in the critical analysis of the arts, media, technology and information systems to enhance the quality of life.

A Reflective and Creative Thinker who
CGE3a -recognizes there is more grace in our world than sin and that hope is essential in facing all challenges;
CGE3b -creates, adapts, evaluates new ideas in light of the common good;
CGE3c -thinks reflectively and creatively to evaluate situations and solve problems;
CGE3d -makes decisions in light of gospel values with an informed moral conscience;
CGE3e -adopts a holistic approach to life by integrating learning from various subject areas and experience;
CGE3f -examines, evaluates and applies knowledge of interdependent systems (physical, political, ethical, socio-economic and ecological) for the development of a just and compassionate society.

A Self-Directed, Responsible, Life Long Learner who

CGE4a -demonstrates a confident and positive sense of self and respect for the dignity and welfare of others;

CGE4b -demonstrates flexibility and adaptability;

CGE4c -takes initiative and demonstrates Christian leadership;

CGE4d -responds to, manages and constructively influences change in a discerning manner;

CGE4e -sets appropriate goals and priorities in school, work and personal life;

CGE4f -applies effective communication, decision-making, problem-solving, time and resource management skills;

CGE4g -examines and reflects on one's personal values, abilities and aspirations influencing life's choices and opportunities;

CGE4h -participates in leisure and fitness activities for a balanced and healthy lifestyle.

A Collaborative Contributor who

CGE5a -works effectively as an interdependent team member;

CGE5b -thinks critically about the meaning and purpose of work;

CGE5c -develops one's God-given potential and makes a meaningful contribution to society;

CGE5d -finds meaning, dignity, fulfillment and vocation in work which contributes to the common good;

CGE5e -respects the rights, responsibilities and contributions of self and others;

CGE5f -exercises Christian leadership in the achievement of individual and group goals;

CGE5g -achieves excellence, originality, and integrity in one's own work and supports these qualities in the work of others;

CGE5h -applies skills for employability, self-employment and entrepreneurship relative to Christian vocation.

A Caring Family Member who

CGE6a -relates to family members in a loving, compassionate and respectful manner;

CGE6b -recognizes human intimacy and sexuality as God given gifts, to be used as the creator intended;

CGE6c -values and honours the important role of the family in society;

CGE6d -values and nurtures opportunities for family prayer;

CGE6e -ministers to the family, school, parish, and wider community through service.

A Responsible Citizen who

CGE7a -acts morally and legally as a person formed in Catholic traditions;

CGE7b -accepts accountability for one's own actions;

CGE7c -seeks and grants forgiveness;

CGE7d -promotes the sacredness of life;

CGE7e -witnesses Catholic social teaching by promoting equality, democracy, and solidarity for a just, peaceful and compassionate society;

CGE7f -respects and affirms the diversity and interdependence of the world's peoples and cultures;

CGE7g -respects and understands the history, cultural heritage and pluralism of today's contemporary society;

CGE7h -exercises the rights and responsibilities of Canadian citizenship;

CGE7i -respects the environment and uses resources wisely;

CGE7j -contributes to the common good.

Unit 3: Evolution

Time: 20 hours

Unit Description

In this unit students investigate the theory of evolution, its development, evidence that supports it, and mechanisms that explain it. Students identify questions that arise from concepts of evolution and diversity, solve problems using the Hardy-Weinberg equation, and conduct investigations relating to evolution. This unit builds on concepts introduced in the Diversity, Genetic Continuity, and Cellular Functions units from the Grade 11 University Preparation Biology course, and from the first two units of this course. Evolution is presented to students within a Catholic context that views reality through the eyes of faith and challenges students to grow in a fuller understanding of their faith. Appendix 5: The Serpent and the Soul (A Catholic Perspective on Bioethical Issues) is a resource and reflection. It contains questions that students can answer as they work through this unit. In this unit, students could divide the pages in their Journeyer's Journal vertically in half. One side of the page could be devoted to moral/ethical reflections and questions, while the other side could be devoted to their questions, hypotheses, and thoughts on scientific ideas and concepts that arise throughout this unit. Using a split page, students and teachers can visually track their ideas and questions. Current issues, for example, those relating to biotechnology that were introduced in the Molecular Genetics unit, could be used to stimulate reflective thinking in this unit and be included in students' Journeyer's Journal. Students should be encouraged to seek correlations between the units in this course and reflect on how their thoughts/faith have changed as a result of class discussions and individual reflections.

The first activity introduces the historical and cultural context of evolution using various sources, including the Scopes Trial (excerpts from the play or video could be used). Students participate in a small group activity in which students explore the culture, history, and development of the theory of evolution by analysing a variety of items selected. Students then research the work of individuals or events, and make a conceptual timeline of their contribution to evolution. In their Journeyer's Journal, students identify questions relating to the theological, ethical, and conceptual issues of evolution and diversity.

In the second activity, students learn about the critical role that evidence plays in the development of a theory. Using their timeline from Activity One, they identify different examples of evidence that have influenced the development of the theory of evolution. Using a case study or other inquiry activity, students analyse the ability of one or more types of evidence to support a hypothesis that explains the theory of evolution, communicating their results in a discussion paper. Students describe and analyse examples of how technology has influenced our understanding of evolution.

In the third activity, students use a model to simulate Hardy-Weinberg equilibrium. Students develop and use sampling procedures to gather data based on simulations of the peppered moth studies. Using their results, students explain the process of adaptation of organisms to their environment.

In Activity Four, students study the mechanisms associated with speciation (microevolution, reproductive isolation, and geographical mechanisms) and apply those mechanisms to explain speciation in Darwin's finches.

In Activity Five, students investigate the mechanisms of the evolution of a specific molecule, cytochrome c, by means of current research in molecular genetics.

It is recommended that a summative test be given as Activity Six. This test should be rigorous and reflect the depth of knowledge required in this unit. This unit involves the use of higher-level thinking skills which some students may require help developing. The approach suggested leads students to become creative and critical thinkers. Group work is included in each activity. The structure of the groups from one lesson to the next may vary or be consistent; the approach taken should meet the individual needs of the class. Although students work in groups, teachers are reminded to ensure that the final product is the individual student's work. In any group activity that requires a single product for submission, each student's work must be assessed individually.

Each of these activities cluster expectations in a way that allows students to sequentially develop the skills and understanding of the rationale for the theory of evolution.

Unit Synopsis Chart

Activity	Time	Learning Expectations	Assessment Categories	Tasks
1. A Walk Through Time	4 hours	EVV.02, EVV.03, EV1.02, EV2.02 CGE 1h, 1i, 2e, 3c, 5a, 5e, 5f SIS.05, .06	Knowledge, Communication, Making Connections	- Students identify the significance of items to evolution (ask/ponder questions about links) - Students prepare a timeline (scientific and cultural)
2. Looking for Evidence	3.5 hours	EVV.02, EVV.03, EV2.01, EV2.02, EV2.05, EV3.02 CGE 2d, 3c SIS.05, .10	Inquiry Making Connections	- Students investigate specific examples of different types of evidence for evolution and the hypotheses that they support - Students complete a case study or inquiry activity investigating evidence supporting the theory and produce a discussion paper
3. Microevolution 3.1 The Hardy-Weinberg principle 3.2 Mechanisms of Microevolution	5 hours	EVV.01, EV1.03; EV2.03, EV2.04 CGE 3c, 5a SIS.05, .06, .07	Inquiry Knowledge Inquiry	- Students investigate the Hardy-Weinberg principle using a model - Students study the mechanisms of evolution and investigate directional selection - Students develop and use sampling procedures to simulate the peppered moth study
4. Speciation	4 hours	EVV.01, EV1.01, EV1.03, EV1.04 CGE 3c, 5a SIS.05	Knowledge	- Students study the mechanisms of speciation and apply the concepts to Darwin's finches
5. Cytochrome c	2.5 hours	EVV.03, EV3.01 CGE 3c SIS.05	Making Connections	- Students apply current research in molecular genetics to analyse the evolution of cytochrome c
6. Test	1 hour		Knowledge Communication Making Connections	Students complete a unit test

Activity 1: A Walk through Time

Time: 4 hours

Description

Students define evolution and learn about its position as the cornerstone of biological sciences, as well as its role in explaining the diversity of living things. Students work cooperatively to analyse elements associated with the theory of evolution. Through independent research of a major event or person involved in the development of evolutionary theory, students create a thorough timeline of evolution in a historical and cultural context. Students reflect on the Church's past and present views on the theory of evolution.

Strand(s) & Learning Expectations

Strand(s): Evolution

Ontario Catholic School Graduate Expectations

CGE 1h - respects the faith traditions, world religions and the life journeys of all people of good will;
CGE 1i - integrates faith with life;
CGE 2e - uses and integrates the Catholic faith tradition, in the critical analysis of the arts, media, technology, and information systems to enhance the quality of life;
CGE 3c - thinks reflectively and creatively to evaluate situations and solve problems;
CGE 5a - works effectively as an interdependent team member;
CGE 5e - respects the rights, responsibilities and contributions of self and others;
CGE 5f - exercises Christian leadership in the achievement of individual and group goals.

Overall Expectations

EVV.02 - evaluate the scientific evidence that supports the theory of evolution;
EVV.03 - 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

EV1.02 - describe, and put in historical and cultural context, some scientists' contributions that have changed evolutionary concepts;
EV2.02 - identify questions for investigation that arise from the concepts of evolution and diversity.

Scientific Investigation Skills

SIS.05 - 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;
SIS.06 - compile, organize, and interpret data, using appropriate formats and treatments, including tables, flowcharts, graphs, and diagrams.

Planning Notes

- Gather a collection of items associated with evolution (e g., newspaper headlines, comics, cladograms, fossils, skeletons, pictures; see resources for sources) and organize them into groups that represent different elements associated with the development of the theory of evolution, such as: investigation, research, supporting evidence, controversy, people, and diversity.
- Preview a video that presents evolution in a historical and cultural context and illustrates the controversy that surrounded its development (see resources for suggestion). Select an excerpt that illustrates the points above.
- Become familiar with the Catholic Church's teachings on evolution. Misconceptions about Creationism are an example of a misguided attempt to apply the theological truth of Genesis to the scientific truth of the evolution theory. Students should be made aware of the current teachings on evolution (see resources).

- Arrange for access to the library/resource centre or computers for student research.
- Prepare the criteria and assessment scheme for the timeline report and presentation.
- Have available chart paper or poster paper cut into squares or "tiles" for students to use to create a classroom-sized timeline.

Teaching/Learning Strategies

The teacher:

- Introduces the topic of evolution (video clips or selected readings based on the Scopes Trial may be used), defines evolution as change through time, and explains the role of evolution in diversity and classification (that is, the reason why organisms can be classified according to their similar features is common ancestry).
- Explains the importance of evolution to biology as the organizing principle that connects the various biological disciplines to one another, including molecular biology, anatomy, and embryology.
- Describes the introductory group activity in which students explore the culture, history, and development of evolution by analysing a variety of items organized into groups around the classroom (last station may include video excerpt or essay). (SIS.05)
- Instructs students to perform two tasks at each station:
  - to collectively describe the connection between the items and evolution by suggesting answers to the question "What do these items reflect about evolution?" and recording their answers on chart paper
  - to reflect on and inquire further into evolution by individually identifying conceptual or ethical questions resulting from the discussion and analysis at each station, and recording these questions in their Journeyer's Journal. (EV2.02)
- Facilitates a class discussion about students' observations and helps identify the ideas the items reflect about evolution (for example, evolution as a process of change; types of evidence that support evolution; the role of analysing similarities and differences among organisms; the controversy surrounding the study and acceptance of evolution; important people involved in its development; its influence on history and culture; and the influence of culture and history on its development).
- Introduces the timeline investigation assignment in which students independently research the impact of an individual or event on the development of evolutionary theory (see Appendix 1). Initial class discussion about this assignment allows students to demonstrate their prior knowledge from Grade 11 biology. Students communicate the information in both a written summary (a "tile" or square piece of chart paper with the information used to construct a class-sized "walk through time") and an oral presentation to the class, allowing the class to develop a complete historical and cultural timeline of evolutionary theory development. (EV1.02, SIS.05, SIS.06)
- Introduces each presentation in chronological order, allowing for the sequential unfolding of events and societal responses. **Note:** as necessary, address any misconceptions students may present.
- Assesses presentation and written summary using an appropriate assessment tool. (EV1.02)
- Summarizes development of the theory of evolution, stresses people and events of significant influence, and describes the position of evolution in society today as a fact. In addition, the Church's teachings on evolution should be presented. Students could be asked to research what is accepted today, using appropriate websites.
- Instructs students to make journal entries reflecting on how and when the Church changed its views on science, specifically the theory of evolution (see Appendix 5).

Students:

- Work in small groups to analyse items associated with evolution and draw connections between the items and evolution, putting their ideas on chart paper. (SIS.05)
- Identify conceptual and ethical questions that have evolved from group discussions at each station, and record these in their Journeyer's Journal. (EV2.02)
- Research the major impact of an individual or event on the development of evolutionary theory, including a brief synopsis of the societal impact of the work at that time, and present this information in the form of an oral presentation and a "tile" (written summary/picture) that is placed/hung in the classroom, resulting in the construction of a complete timeline. (EV1.02, EV.2.02)
- Record the information from other students in the class and organize it into a concise individual timeline.
- Make a reflection in their journal about the development of the theory of evolution, and the role of the Church and its current teachings on evolution. (EV1.02)

Assessment & Evaluation of Student Achievement

- Assess the timeline tile for Knowledge/Understanding, Communication, and Making Connections, using a rating scale or rubric. (EV1.02)
- Assess the timeline presentation for Knowledge/Understanding, Communication, and Making Connections, using a rating scale. (EV1.02)
- Peer assessment of student summaries may be done using a checklist.
- Assess the Journeyer's Journal for scientific questions using a rubric or rating scale. (EV2.02)

Accommodations

- Students with physical and learning disabilities are encouraged to use the computer. Peer assistance should be encouraged.
- Students may videotape their presentations.
- For consolidation or enrichment, students may complete a book report on Darwin's *Origin of Species* or the work of Thomas Malthus.
- For consolidation or enrichment, students may research original journal articles written by Malthus, Darwin, Wallace, etc., then read and critique them.
- For further explanation and interest, students may research the impact the Church had on the development of the theory of evolution.

Resources

Text

Campbell, Neil. *Biology*. Don Mills, Ontario: Benjamin/Cummings Publishing, 1987. ISBN: 0-8053-1840-2

Darwin, Charles. *The Origin of Species*. Hertfordshire, England: Cumberland House, 1998. ISBN 1-853-26780-5 (**Note:** the text reprinted here is the first November 1859 edition)

Galbraith, Don. *Biology*. Toronto, Ontario: John Wiley & Sons, 1989. ISBN: 0-471-79629-8

Gould, Stephen J. *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time*. Harmondsworth, England: Penguin, 1990.

Gould, S.J. *Bully for Brontosaurus*. New York, NY: W.W. Norton, 1991. ISBN 0-393-02961-1 (essay)

Gould, S.J. *Ever Since Darwin*. New York, NY: W.W. Norton, 1977. ISBN 0-393-00917-3 (essay)

Gould, S.J. *Full House: The Spread of Excellence from Plato to Darwin*. New York, NY: Harmony Books, 1996. ISBN 0-517-70394-7

Gould, S.J. *Ontogeny & Phylogeny*. Cambridge, MA: The Belknap Press of Harvard University Press, 1977. ISBN 0-674-63941-3

Gould, S.J. *Wonderful Life: The Burgess Shale and the Nature of History*. New York, NY: W.W. Norton, 1989. ISBN 0-393-02705-8

Websites

Evolution: Controversy through Time – http://www.pbs.org.wgbh/evolution/educators/lessons/lesson7/act1notes.html

Evolution: Scopes Trial – http://www.pbs.org/wgbh/evolution/educators/lessons/lesson7act2.html

Evolution – http://www.pbs.org/wgbh/evolution/index.html

Evolution Introduction – http://www.accessexcellence.com/bioforum/bf02/scott/bf02a01.html

Teaching about evolution and the nature of science – http://www.nap.edu/readingroom/books/evolution98/

The Scopes 'monkey trial' media circus – http://www.dimensional.com/~randl/scopes.htm

Evolution – http://www.rci.rutgers.edu/~ecolevol/fulldoc.html#biocont

Alfred Lord Tennyson's "In Memoriam" – http://www.bluffton.edu/~humanities/2/tennyson.htm

Evolution debate continues – http://www.cnn.com/2000/LAW/07/13/scopes.monkey.trial/

Overview of religion, culture and evolution – http://www.nhc.nc.us:8080/tserve/twenty/tkeyinfo/tscopes.htm

The Vatican: Catechism of Catholic Church – http://www.vatican.va/archive/catechism/ccc_toc.htm

Canadian Conference of Catholic Bishops – http://www.cccb.ca/

Video

Inherit the Wind. MGMUA, California. 1960. ISBN 0792807499

Evolution: Darwin's Story. WGBH/NOVA Science Unit & Clear Blue Sky Production. 2001.

Appendices

Appendix 1 – Teacher's Notes: The Timeline

Appendix 1

Teacher's Notes: The Timeline

Each student is responsible for presenting information on a person or organization that has influenced the development of evolutionary theory. The students have up to one class period to research the information and organize a written and oral summary; therefore, the information should be straightforward, describing their topic only with respect to its impact on evolutionary theory. The topics listed below include a variety of people who have contributed answering the challenge of evolution, and therefore a timeline that includes such contributions will reflect the cultural, religious, and scientific views that have accompanied the development of evolutionary theory throughout history.

Students should be encouraged to present their information in a manner that illustrates the common beliefs and reactions at the time; for example, they could role-play their individual or organization.

1700s - Carolus Linnaeus, Comte de Buffon, Erasmus Darwin, Reverend Thomas Malthus

1800s - Jean-Baptiste de Lamarck, Georges Cuvier, Charles Lyell, Darwin's Beagle voyage, Alfred Russel Wallace, Darwin's *Origin of Species*, Gregor Mendel, Thomas Huxley, Charles Hodge, Othniel Charles Marsh, Rev. W. Herbert, Professor Grant, Professor Haldeman, Dr. Freke, Mr. Herbert Spencer (contrasted theories of Creation and Organic Evolution), Rev. Baden Powell

1900s - William Jennings Bryan, Lysenko, The Scopes Trial, Neo-Darwinism, Pope Pius XII, Vincent Sarich and Allen Wilson, Mary Claire King and Allen Wilson, Donald Johanson and "Lucy", E.O. Wilson, Pope John Paul II, Dr. Arthur Peacocke, Stephen Jay Gould, Niles Eldridge Michael Ruse, Davidson Black (Canadian who discovered fossils of Peking man, a human ancestor near China, setting stage for contemporary investigation of human evolution).

Activity 2: Looking for Evidence

Time: 3 hours

Description

Students learn about the critical role that evidence plays in the development of a theory. Using their timelines, they identify different examples of evidence that have influenced the development of the theory of evolution. They learn about the major types of evidence that have led to the acceptance of Darwin's theory of evolution, including bio-geographical, molecular, homological (anatomical and developmental), and fossil, and the technology that has made it possible to collect this evidence. Students then analyse the ability of one or more of these types of evidence to support the hypotheses that explain the theory of evolution, and present their findings in a discussion paper.

Strand(s) & Learning Expectations

Strand(s): Evolution

Ontario Catholic School Graduate Expectations

CGE 2d - writes and speaks fluently in one or both of Canada's official languages;
CGE 3c - thinks reflectively and creatively to evaluate situations and solve problems.

Overall Expectations

EVV.02 - evaluate the scientific evidence that supports the theory of evolution;
EVV.03 - 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

EV2.01 - outline evidence and arguments pertaining to the origin, development, and diversity of living organisms on Earth;
EV2.02 - identify questions to investigate that arise from concepts of evolution and diversity;
EV2.05 - formulate and weigh hypotheses that reflect the various perspectives that have influenced the development of the theory of evolution;
EV3.02 - describe and analyse examples of technology that have extended or modified the scientific understanding of evolution.

Scientific Investigation Skills

SIS.05 – 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;
SIS.10 – identify and describe science-and technology-based careers related to the subject area under study.

Planning Notes

- Choose an article, case study, or activity that describes in detail one or more types of evidence that have been used to support the theory of evolution (see Resources for ideas). Suggest students use resources other than molecular evidence, because Activity 5 in this profile is based on cytochrome c. Organize necessary materials for the selected activity.
- Prepare a rubric to evaluate student discussion paper.
- Gather examples of evidence (some may be taken from previous activity, such as fossil samples, comparative embryological pictures, *Archaeopteryx* fossil picture, models of skeletons).
- Preview a video that describes technology used in cladistics/evolutionary studies.

Teaching/Learning Strategies

The teacher:

- Introduces the important role of evidence by referring to the previous day's discussion about the development of evolution and posing the question, "Evolution is widely accepted as a fact today – Why?" Students should recognize "sufficient evidence" as the reason for this acceptance.
- Describes the connection between hypotheses and predictions, and evidence in the development of any scientific theory, and states and explains the hypotheses that have influenced the search for evolutionary evidence and have assisted in the development and acceptance of evolutionary theory. Distinguish among hypothesis, theory and law by clarifying why the theory of evolution is not the law of evolution. (Refer to Appendix 2.) (EV2.05)
- Instructs students to analyse their timelines and look for examples of evidence that have influenced the development of the theory of evolution, and the technology that has improved the ability to find the evidence. Students share their ideas with the class, and from the discussion, extract the major types of evidence that support evolution, specifically: molecular (e.g., Vincent Sarich and Allen Wilson and the comparison of DNA between humans and apes); homological; fossil (e.g., Donald Johnson and Lucy); and bio-geographical (e.g., Darwin's finches). Aid students in making a web diagram of the findings. Introduce the role of technological advances in the development of the theory. (EV3.02)
- Introduces each of the different types of evidence by describing a situation in which each has been used to confirm hypotheses. Presents each form of evidence socratically, in terms of what they are, how they are obtained (making reference to various technological advances, e.g., radiometric age dating, DNA fingerprinting), and what they illustrate. Uses models and pictures to represent evidence if available. (EV2.01, EV3.02)
- Outlines the inquiry assignment in which students individually analyse a case study that represents the use of one or more types of evidence for evolution (activity should be based on bio-geographical or fossil evidence, as molecular evidence appears again in Activity 5). Students follow the outlined procedure for the activity and describe the types of evidence represented and the hypothesis(es) supported. Students provide an analytical explanation of how and why the evidence supports the hypothesis. Their observations are summarized in the form of an individual discussion paper. (EV2.01; SIS.05. CGE 2e)
- Provides an outline of how to write a proper discussion paper and provides an appropriate assessment tool for it.
- Allows time for the students to record scientific and theological questions about the diversity of living things, the significance of a theory to science, and specifically the significance of this theory to biology, in their Journeyer's Journal. Students could read sections from Appendix 5 – Serpent and Soul and discuss or reflect on it. (EV2.02, CGE 3c)

Students:

- Recognize through class discussions the importance of hypotheses in the development of any scientific theory, and then use their timelines to search for evidence that supports the theory of evolution. Make a web diagram of the major types of evidence that supports evolution. (EV2.05)
- Identify technologies that have helped to improve the search for evidence, and share this information with the class. (EV3.02, SIS.10)
- Recognize the importance of evidence and the need to evaluate the quality of evidence in the scientific exploration of a theory.

- Work in small groups on a case study or other activity to investigate a specific example of the one type of evidence and the hypotheses that it supports (e.g., the divergence of Darwin's finches provides bio-geographical evidence for evolution). (EV2.01, SIS.05. CGE 3c)
- Present their observations in the form of a discussion paper entitled, "Evidence for Evolution," following the outline provided. (EV2.01. SIS.05, CGE 2e)
- Reflect on and record questions pertaining to the scientific and theological nature of genetic diversity and the significance of the theory of evolution to their lives in their Journeyer's Journal. (EV2.02)

Assessment & Evaluation of Student Achievement

- Assess the discussion paper for Knowledge/Understanding, Inquiry, and Communication, using a rubric or marking scheme. (EV2.01)
- Assess the Journeyer's Journal for scientific questions using a rubric or rating scale. (EV2.02)

Accommodations

- Students with physical and learning disabilities are encouraged to use the computer. Peer assistance should be encouraged where appropriate. See resources for online fossil activities.
- Activity stations must be accessible for students with physical limitations, e.g., wheelchair accessible.
- For enrichment, students may visit a museum (or do an online museum tour; see resources) to view and report on an evolution display, or interview an individual involved in researching current initiatives in evolution and report on their area of investigations. Students can borrow a collection of fossils and describe the process of collecting and analysing the fossils and the evidence that the particular collection provides.

Resources

Internet

The Nature of Fossils – http://anthro.palomar.edu/time/time_1.htm

Evidence of Evolution – http://anthro.palomar.edu/evolve/evolve_3.htm

Whales in Transition Activity – http://www.indiana.edu/~ensiweb/lessons.wh.fm.tr.html

Evolution Activities – http://www.indiana.edu/~ensiweb/evol.fs.html

Evolution – http://www.pbs.org.evolution

Teaching Evolution – http://www.ucmp.berkeley.edu/history/evolution.html

The Scientific Method and Evidence for Evolution – http://www.utm.edu/~rirwin/391EvidEvol.htm

Evidence for Evolution – http://www.nova.edu/ocean/bio/1060/evolution1.html

Royal Tyrrell Museum – http://www.tyrrellmuseum.com/tour/entry.html

Online Chapter on Evolution
– http://www.gened.emc.maricopa.edu/bio/bio181/BIOBK/BioBookEOL11.html

Online fossil evidence of horse evolution
– http://www.flmnh.ufl.edu/natsci/vertpaleo/fhc/fhc.htm

Writing Scientific Papers – http://www.unlv.edu/staff/cherr/bio191/report2htm
– http://www.wisc.edu/writing/Handbook/science/report.html#Discussion

Learning from the Fossil Record – http://www.ucmp.berkeley.edu/fosrec

Evolution Activities – http://www.ucmp.berkeley.edu/history/evolution.html

Suggestions for Inquiry activities

Whales in Transition – http://www.ucmp.berkeley.edu/history/evolution.html
Evolution Activities – http://www.indiana.edu/~ensiweb/evol.fs.html
Island Biogeography and Phylogeny – http://www.ucmp.berkeley.edu/fosrec/Filson.html
(although, does include a molecular analysis)

Text

Campbell, Neil. *Biology*. Don Mills, Ontario: Benjamin/Cummings Publishing, 1987. ISBN 0-8053-1840-2

Galbraith, Don. *Biology*. Toronto, Ontario: John Wiley & Sons, 1989. ISBN: 0-471-79629-8

Understanding Biology Text

"Investigating Polar Bear and Giant Panda Ancestry" *The American Biology Teacher*. Volume 63, No. 9, November/December 2001

Appendices

Appendix 2 – Predictions About Evolution

Appendix 2

Predictions About Evolution

Prediction 1
If members of a group evolved from a common ancestor, then they should show similarities in their structure, embryology, and at the molecular level.

Prediction 2
If evolution has occurred, one would expect to find evidence that organisms living in the past have changed, producing those that live today.

Prediction 3
Islands have most likely been colonized by organisms that dispersed from the nearest mainland. Once on an island, the colonizing species, which may be isolated, may evolve in different ways from its relatives on the mainland.

Activity 3: Microevolution

Time: 5 hours

Description

In this activity students use a model to simulate the Hardy-Weinberg principle in a non-evolving population. Students use beads to represent alleles in the gene pool of a population, and randomly combine alleles to form diploid organisms. They simulate several generations of random mating and determine the frequency of the alleles after each generation. They compare their experimental results with the predicted results using the Hardy-Weinberg principle and consider the consequences on the population if there is a significant change, e.g., if geographical isolation occurs. They also study the causes of microevolution by investigating the peppered moth study.

Strand(s) & Learning Expectations

Strand(s): Evolution

Ontario Catholic School Graduate Expectations

CGE 3c - thinks reflectively and creatively to evaluate situations and solve problems;
CGE 5a - works effectively as an interdependent team member.

Overall Expectations

EVV.01 - analyse evolutionary mechanisms, and the processes and products of evolution;

Specific Expectations

EV1.03 - analyse evolutionary mechanisms and their effects on biodiversity and extinction;
EV2.03 - solve problems related to evolution using the Hardy-Weinberg equation;
EV2.04 - develop and use appropriate sampling procedures to conduct investigations into questions related to evolution.

Scientific Inquiry Skills

SIS.05 - locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, using appropriate library and electronic research tools, including Internet sites;
SIS.06 - compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams;
SIS.07 - communicate the procedures and results of investigations and research for specific purposes using data tables and laboratory reports.

Prior Knowledge & Skills

- Biology, Grade 11, University Preparation: Diversity of Living Things and Genetic Continuity (Definitions of the terms gene, allele, chromosome, homologue, monoploid, diploid; recall the Laws of Independent Assortment and Segregation.)

Planning Notes

- Make copies of the Hardy-Weinberg principle inquiry for students (refer to Appendix 3) or see resources for alternate activities.
- This activity requires students to use a binomial expansion equation, some students may need to review this before beginning this activity.

- Students require the following for Appendix 3 activity: two different-coloured paper clips (alternatively, the beads used to make coupled necklaces or diatomic molecules from chemistry modelling kits could be used). Each gene pool is composed of one hundred paper clips or beads (60 of one colour, 40 of the other). To house the paper clips or beads representing the random selection of alleles, and to hold the mating pairs, each group will require three beakers or containers with a sufficiently large opening so that a hand can be inserted comfortably. Each colour of paper clip or bead goes into a container, and the third container receives the selected alleles.
- Create a spreadsheet to record data with 7 rows each containing 20 cells, one for each allele. These cells are to be paired to represent the diploid condition of the gene (refer to Appendix 3). The rows will be labelled as follows:
  1. genotypes of the parents
  2. the second parental mating pairs
  3. F1 offspring
  4. F1 mating pairs
  5. F2 offspring
  6. F2 mating pairs
  7. F3 offspring
- To accompany the investigation, create a question sheet which requires students to apply the Hardy-Weinberg principle to different scenarios.
- Provide access to computers, or provide materials for the students' research on the mechanisms of microevolution.
- Provide a chart graphic organizer for students to complete during the presentation. The chart will list the causes of microevolution on the vertical axis, and mechanism, significance, and effects on genetic variation on the horizontal axis.
- Become familiar with the peppered moth story.
- Collect materials for the peppered moth simulation of directional selection. Students will require the following: construction paper (two sheets, each of a different colour, one of a neutral colour), scissors, and a hole punch. The coloured paper represents the different colours of bark on the trees. "Moths" should be cut/punched out from each of the two non-neutral coloured sheets of paper, and then placed on each of the three sheets of construction paper. We suggest that one will have cryptic colouration as it sits on a background of its own colour; the third piece is a neutral control showing that neither species has an advantage on a neutral background. The neutral colour should show a good contrast with both moth colours. Students must include in their design a method to account for the reproduction of the moths after each generation or timed interval.

Teaching/Learning Strategies

Activity 3.1: The Hardy-Weinberg Principle

The teacher:

- Presents background about population genetics.
- Introduces the Hardy-Weinberg principle through an investigation, noting these key points: the equation, random mating, large populations, etc (see Appendix 3).
- Connects the Hardy-Weinberg principle to evolution, as demonstrable proof of evolution acting on a population. Shows students how evolutionary forces such as genetic drift, gene flow, non-random mating, etc., work to drive populations away from predicted frequencies.

The students:

- Conduct an investigation (Appendix 3) into the Hardy-Weinberg principle, recording their observations and answering related questions and define key terms like populations, gene pool, and genetic variation. (SIS.06; .07, EV2.03)
- Recognize the importance of the Hardy-Weinberg principle to the study of evolution.

Activity 3.2: Mechanisms of Microevolution

The teacher:

- Instructs students to read a text or other appropriate materials that outline the causes of microevolution, and to summarize the information in a concept map.
- Discusses the factors that cause microevolutionary change in a gene pool (i.e., genetic drift, gene flow, mutation pressure, assortive mating, natural selection).
- Divides the students into five groups, one for each of the causes of change in a gene pool, and assigns the students the task of researching and explaining an example(s) of the assigned cause to the class.
- Provides a chart graphic organizer for students to complete during the presentations (EV1.03).
- Monitors the presentations, making sure students are discussing the causes of microevolutionary change and recording the discussion in their organizers.
- Discusses microevolution through directional selection with students, uses the peppered moth as an example of directional selection, and introduces the concept of multiple generations to evolution.
- Instructs students to design and use a model simulating the peppered moth study, using the materials provided, and to record their results in charts then graphs, and analyse the results in terms of microevolution. (The coloured paper represents the different colours of bark on the trees; moths should be cut from each of the two colours used - see Planning Notes for more details.) (EV2.04)
- Makes sure that the students sample several generations and incorporate the generation of offspring into the model. Students should also have a limited time to sample and collect as many moths as possible. The moths should be relatively small and the shape is not as important as the colour.
- Confers with students about their model prior to their using it, and where appropriate, guides students to rethink elements of the design or sampling techniques and the appropriateness of their charts for recording data.
- Designs questions related to the microevolution and the limitations of the model for the students to answer and submit with results, e.g., the students should identify the mechanism as directional selection, and could hypothesize under what conditions this might lead to the evolution of a new species. (EV1.03, 1.04; SIS.06, .07).

The students:

- Read the sections of the text or other appropriate materials on the causes (genetic drift, etc.) of microevolution and construct a graphic organizer (e.g., concept map) summarizing the information.
- Use the Internet or library/resource centre (or materials provided by the teacher) to research a specific cause of microevolution.
- Make a brief (5 min.) presentation explaining the cause and giving an example of the assigned causes of microevolution. (EV1.03)
- Complete the chart graphic organizer during their peers' presentations on the causes of microevolution. (EV1.03)
- Design and test a model to simulate the peppered moth study; record data in tables, construct a graph based on the results, and identify the limitations of the model, using the materials provided by the teacher. (EV1.03, 1.04; EV2.04; SIS.06, .07)

Assessment & Evaluation of Student Achievement

- Assess the graphic organizer of causes of microevolution for Knowledge and Communication, using a checklist (EV1.03).
- Assess the report on the investigation for Inquiry (the completion of the observation chart and the construction and use of a summary chart) and the responses to the questions related to the application of the Hardy-Weinberg principle. (SIS.06, .07, EV2.03)
- Assess individual presentations on causes of microevolution for Knowledge and Making Connections, using a checklist or rating scale. (EV1.03)
- Assess the chart graphic organizers on the causes of microevolution for Knowledge, using a marking scheme designed for the purpose. (EV1.03)
- Assess the peppered moth report for knowledge of directional selection (EV1.03, SIS.07), and the design of the model and appropriateness of the sampling techniques (EV2.04, SIS.06) for Inquiry, using a marking scheme

Accommodations

- Students who have difficulty manipulating fine materials should use the paper clips for the alleles in the Hardy-Weinberg inquiry.
- Students with visual difficulties should have access to enlarged charts and organizers.
- Students with visual difficulties should have access to large-sized moths and an extended time period for sampling.

Resources

"Hardy-Weinberg Equilibrium and Evolution: A Lab Exercise." *The American Biology Teacher*, Volume 63, Number 9. Nov/Dec 2001

Franzoni, Orfeo. "Population Genetics and Evolution." Ward's Natural Science Establishment, Inc. (Simulation Game.)

Websites

A Simple Demonstration of the Hardy-Weinberg Principle – http://www.georgetown.edu/departments/biology/class/hardy/hardy2.html

Genetic Drift – http://darwin.eeb.uconn.edu/simulations/drift.html

Genetic Drift Simulation – http://www.biology.arizona.edu/evolution/act/drift/about.html

Hardy-Weinberg Problem – http://biology.nebrwesleyan.edu/viets/hw/bio1hwans.html

Hardy-Weinberg Equilibrium Model – http://anthro.palomar.edu/synthetic/synth_2.htm

Micoeveolution – http://www.zo.utexas.faculty/sjasper/bio304/microevol.html

Natural Selection and Genetic Drift Modeling Exercise – http://fmc.utm.edu/~rirwin/NatSelModIntro.htm

Population Genetics & Hardy-Weinberg Equilibrium – http://www.baa.duke.edu/baa93/h-weq.htm

Appendices

Appendix 3 – MN Blood Groups and the Hardy-Weinberg Principle

Appendix 3

MN Blood Groups and the Hardy-Weinberg Principle

Background: This model assumes that a population has only two alleles at a given locus. The frequency of the alleles is 60% M (p =0.6) and 40% N (q =0.4). According to the Hardy-Weinberg principle for a diploid population, the frequency of each genotype is $p^2 + 2pq + q^2 = 1$. where p^2= MM, 2pq = MN, q^2 = NN. In this population, the predicted frequency of p^2=0.36, and 2pq =0.48 and q^2 =0.16. The first part of the model places all the alleles in a jar to represent the gene pool for the population. Students randomly select two alleles for each individual from the gene pool (law of independent probability). They will create ten individuals that will be the Parental generation (P_1) for the model. Students place the ten individuals (diploid) into a container and select two at a time to represent the mating pairs. They record this on their observation sheet. Next, they simulate the genetic reassortment during sexual reproduction. Each mating pair of individuals produces two offspring. The genotypes of the offspring are determined by the genotypes of the parents. Where the parents are homozygous at a locus, the gametes will all contain that allele. Where the parents are heterozygous at a locus, the gametes have an equal probability of containing either of the alleles. In order to replicate the independent probability that either allele could be involved in fertilization, students flip a coin to determine which allele is passed on (e.g., heads for M and tails for N). The offspring formed represent the First Filial Generation F_1. Students place these individuals back into the mating pairs container and randomly select mating parents from F_1 and then repeat the above procedure for the F_2, F_3 generations. For the F_1, F_2, and F_3 generations, students record the frequency of each of the genotypes and each of the alleles. In order to determine the frequency of M, they use the following formula: Frequency of M = (M/(M+N)) and N = (N/(M+N)) or 1 - frequency of M. They then compare the allelic frequency of the F_1, F_2, and F_3 to that predicted by the Hardy-Weinberg principle.

Purpose

- To use a model to simulate the Hardy-Weinberg principle.

Materials

- 3 containers, 60 black beads*, 40 white beads, recording chart, coins for flipping. The black bead represents the M allele for a blood protein, and the white bead represents the N allele.
  * coloured paper clips could also be used

Method

Place all the beads in one container and mix them up.

1. Record the ratio of M alleles (p) in the gene pool and the ratio of N alleles (q) in the gene pool.
2. Use the Hardy-Weinberg principle to predict the Ratio of MM, MN and NN individuals in a stable non-evolving population.
3. Have one member of the team close his/her eyes or look away, select two beads at a time, and if possible, join them together until there are ten coupled pairs.
4. Record the genotypes of the parental generation on the observation sheet.
5. Place the coupled beads in another container. Have one team member close his/her eyes and randomly select two couples at a time. Place them on the recording sheet in spaces provided for P_1 Mating Pairs.
6. Record the genotypes of the mating pairs on the observation sheet.
   Each mating pair produces two offspring. Where the parent is homozygous at a locus, each gamete will have only one type of allele and that allele is passed on to the next generation. Where an individual is heterozygous at a locus, there will be two types of gametes — one for each allele. Each allele has an equal probability of being passed on. Flip a coin to determine which allele will be passed on to the next generation (use heads for M and tails for N).

Appendix 3 (Continued)

7. Determine the genotypes of the F_1 generation and record them.
   Couple the beads together and place them in the container. Have one member of the group select the mating pairs at random.
   Repeat the process for two more generations.
8. Record the genotypes of the F_1 mating pairs.
9. Record the genotypes of the F_2 offspring.
10. Record the genotypes of the F_2 mating pairs.
11. Record the genotypes of the F_3 offspring.
12. Determine the frequency of each allele (M and N) for each generation of offspring.(M=M/(M+N)), (N=N/(M+N))
13. Compare that frequency to the one predicted in step 1.
14. Compare the frequency of each of the genotypes to that predicted in 2.

Observation Table: MN Blood Groups

Genotypes of Parents									
Genotypes of the P_1 Mating Pairs									
Genotypes of the F_1 Offspring									
Genotypes of the F_1 Mating Pairs									
Genotypes of the F_2 Offspring									
Genotypes of the F_2 Mating Pairs									
Genotypes of F_3 Offspring									

Questions

1. Was genetic equilibrium maintained?
2. If it was not maintained, which of the causes of microevolution might account for that fact? What changes would you make to the model to simulate a condition where the homozygous recessive condition was an advantage to the organism?
3. Would the Hardy-Weinberg equilibrium be maintained in this situation?
4. What type of microevolutionary mechanism would this be?

Activity 4: Speciation

Time: 4 hours

Description

In this activity, students study the mechanisms associated with speciation (microevolution, reproductive isolation, and geographical mechanisms) and apply those mechanisms to explain speciation in Darwin's finches.

Strand(s) & Learning Expectations

Strand(s): Evolution

Ontario Catholic School Graduate Expectations

CGE 3c - thinks reflectively and creatively to evaluate situations and solve problems;
CGE 5a - works effectively as an interdependent team member.

Overall Expectations

EVV.01 - analyse evolutionary mechanisms, and the processes and products of evolution.

Specific Expectations

EV1.01 - define the concept of speciation and explain the mechanisms of speciation;
EV1.03 - analyse evolutionary mechanisms and their effects on biodiversity and extinction;
EV1.04 - explain, using examples, the process of adaptation of individual organisms to their environment.

Scientific Inquiry Skills

SIS.05 - locate, select, analyse, and integrate information on topics under study, working independently and as part of a team using appropriate library and electronic research tools, including Internet sites.

Prior Knowledge & Skills

- Biology, Grade 11, University Preparation: Diversity of Living Things and Genetic Continuity (Mendelian genetics, classification)

Planning Notes

- Collect pictures of closely-related species or organisms, and of varieties of the same species (e.g., *Brassica, Canis familiaris, Columba linia*) to display in class.
- Construct a chart graphic organizer for students to complete during the jigsaw exercises on reproductive isolating mechanisms.
- Book the library/resource centre or arrange for student access to computers, or provide materials for the students research on reproductive isolating mechanisms.
- Provide pictures of and demographic information on Darwin's finches in the Galapagos Islands (see websites).

Teaching/Learning Strategies

The teacher:

- Displays pictures of closely related species and of varieties of organisms belonging to one species.
- Uses the pictures as a resource to guide students to a biological definition of species.
- Distributes chart graphic organizers for students to summarize information from the group work (for example, it could be designed so that the vertical axis/column identifies the types of isolating mechanisms and the horizontal axis/row is used for their definitions such as, "Why this is a barrier to gene flow?").

- Divides class into eight groups and assigns students to them (one group for each type of prezygotic and postzygotic isolating mechanism). Students research and give examples of the assigned mechanism (forming expert groups).
- Monitors, observes, and assists the groups in clarifying concepts as needed.
- Instructs students to reform groups, with at least one member of the eight reproductive isolating mechanisms.
- Outlines the three geographical mechanisms of speciation: allopatric, sympatric, and parapatric, including a description of adaptive radiation.
- Provides background information on Darwin's finches (i.e., location, archipelago, volcanic, no predators, few competitors, different beak structure, similar beak coloration, songs vary with beaks, chart of the distribution of birds, etc.).
- Assigns students to groups of 3 or 4 and assigns each group with the task of being Charles Darwin and writing a report for a scientific journal on the likely origin and mechanisms of speciation of a group of finches on the Galapagos Islands (each student submits an individual report).

The students:

- Read a section of the text or other appropriate materials on reproductive isolating mechanisms and mechanisms of speciation.
- Summarize the information on a concept map. (EV1.01)
- Research and complete the chart graphic organizer for their assigned mechanism.
- Explain their mechanism to the members of the reformed groups. Where there are two members from the same expert group, the students each do part of the presentation.
- Complete the chart graphic organizer for the types of reproductive isolating mechanisms. (EV1.01)
- Work in groups to determine the mechanisms of speciation and then write an individual report or discussion paper for a scientific journal. (EV1.01, 03, 04)

Assessment & Evaluation of Student Achievement

- Peers assess the concept map on speciation using a ranking scale.
- Peers assess concept map on reproductive isolating mechanisms using a ranking scale.
- The teacher will assess the reports/discussion papers for the scientific journal on the origin of different finch species on the Galapagos Islands (key points: single species colonization, allopatry, sympatry, natural selection, ecological opportunity, genetic drift, mutation, genetic variation, adaptive radiation) for Knowledge and Communication using a marking scheme or tool used in Activity 2. (EV1.01, 03, .04)

Resources

Websites

Darwin's Finches – http://rit.edu/~rhrsbi/GalapagosPages/

Finches' beaks – http://terraquest.com/galapagos/education/reference/finchb.html

Macroevolution:Species Formation
– http://www.micro.utexas.edu/courses/levin/bio304/evolution/speciation.html

Speciation – http://www.eldacur.com/~jkimball/BiologyPages/S/Speciation.html

The Beaks of Finches – http://www.accessexcellence.org/AE/AEC/AEF/1996/sprague_beaks.html

The 14 finches of Darwin – http://www.horizon.fr/galapagos/pinsonan.html

Video

Evolution: Darwin's Story. WGBH/NOVA Science Unit & Clear Blue Sky Production. 2001.

Activity 5: Cytochrome c

Time: 2.5 hours

Description

In this activity, students investigate the evolution of cytochrome c using a simulation activity applying concepts of biochemistry, molecular genetics, mechanisms of evolution, and phylogeny.

Strand(s) & Learning Expectations

Strand(s): Evolution

Ontario Catholic School Graduate Expectations

CGE 3c - thinks reflectively and creatively to evaluate situations and solve problems.

Overall Expectations

EVV.03 - 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

EV3.01 - relate present-day research and theories on the mechanisms of evolution to current ideas in molecular genetics.

Scientific Inquiry Skills

SIS.05 - locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, using appropriate library and electronic research tools, including Internet sites.

Prior Knowledge & Skills

- Biology, Grade 11, University Preparation: Diversity of Living Things, Genetic Continuity, and Cellular Functions
- Biology, Grade 12, University: Metabolic Processes and Molecular Genetics (the structure of proteins; action of enzymes; types of mutations to DNA)

Planning Notes

- Copy student worksheets, see Appendix 4.
- Review molecular structure and function of cytochrome c.

Teaching/Learning Strategies

The teacher:

- Introduces the activity with a brief introduction of cytochrome c (structure and function).
- Outlines the inquiry and provides students with the worksheets (see Appendix 4).
- Assists students as required during group work.
- Provides students with a copy of a phylogenetic tree for mammals after they have designed their own based on cytochrome c, for use with question 4 in activity.
- Refers students to Appendix 5 to stimulate student reflection.

Students:

- Work in pairs to complete the activity (each student is responsible for completing their own worksheet).
- Make a journal reflection on present-day views of the theory of evolution.

Assessment and Evaluation of Student Achievement

- Assess the worksheets for Knowledge and Making Connections using a marking scheme. (EV3.01)

Resources

Dickerson, R.E., Scientific American 226 (4): 58-72 (1972).

Voet, D. and J. Voet. *Biochemistry*. John Wiley and Sons Inc., 1995.

Appendix 4

Cytochrome c Simulation of Evolution Investigation

Does the molecular record of Cytochrome c support or refute the theory of evolution?

a.a site	Man/Chimp	Rhesus mon	Horse	Zebra	Sheep	Cat	Rat	Porpoise	Kangaroo	Turkey	Dove	Wood duck	Turtle	Rattlesnake	Frog	Mackerel	Shark
1	K	K	G	G	K	K	K	K	K	K	K	K	K	K	K	W	S
2	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	W	S
3	E	E	D	D	D	D	D	D	E	E	E	E	E	E	E	E	E
4	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
5	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
6	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	R
7	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	A
8	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
9	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
10	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
11	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
12	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
13	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K
14	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K
15	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
16	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
17	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
18	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
19	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
20	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
21	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
22	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
23	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
24	A	A	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
25	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
26	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	I
27	K	K	K	K	K	K	K	K	K	K	K	K	K	N	K	K	K
28	R	R	R	R	T	R	R	R	R	R	R	R	R	R	R	R	R
29	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
30	E	E	E	E	G	G	E	E	E	E	A	A	A	A	A	A	T
31	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
32	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K
33	A	A	E	E	E	A	A	A	A	V	A	A	A	T	Q	Q	Q
34	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
35	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
36	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K	K

Appendix 4 (Continued)

Hydrophilic, acidic D =Asp, E=Glu
Hydrophilic, basic H=His, K=Lys, R=Arg, X=trimethyllys
Polar, uncharged B=Asp, G=Gly, N=Asn, Q=Gln, S=Ser, T=Thr, W=Trp, Y=Tyr, Z=Glu
Hydrophobic A=Ala, C=Cys, F=Phe, I=Ile, L=Leu, M=Met, P=Pro, V=Val

Answer the following questions on the basis of the information provided above and information contained in your textbook.

1. Count the number of types of amino acid at each of the sites and record the answer at the end of each row. Why do you think that at some sites the amino acid never varies?
2. Examine site 22 and note the amino acid at that site. Investigate or identify the chemical properties of those amino acids. Explain why substitutions at this site appear to be limited?
3. Examine site 33. Determine the chemical properties of the amino acid at this site. Explain the variability at this site?
4. For site 33, list the possible genetic codes that would code for each of those amino acid types. Applying your knowledge of mutations, identify the most probable codes for each amino acid and the mutation that is most likely to cause a change from the old amino acid to the new amino acid. Remember to start with the most ancient organism.
5. There is only one amino acid difference between humans, chimps and the rhesus monkey. There is an average difference of 10 amino acids between humans and other mammals; 13 amino acids between humans and birds; 14 amino acids between humans and reptiles; 21 amino acids between humans and fish; 27 amino acids between humans and insects; 45 amino acids between humans and plants. Does this information support or refute the theory of evolution? Why? Why not?
6. Does the overall similarity in cytochrome c between all living organisms support or refute the theory of evolution? Explain.
7. Humans and chimps have no differences in the amino acid composition of cytochrome c. Does this fact alone support or refute the theory of evolution? How could you explain this fact?
8. Draw a phylogenetic tree based on cytochrome c for mammals. How does this tree compare to other phylogenetic trees for mammals? (**Note:** the teacher may need to provide additional resources for this question.)

Appendix 5

The Serpent and the Soul (A Catholic Perspective on Bioethical Issues)

(Written by Ted Laxton, Course Profile writer)

In the great narrative of the Garden of Eden, there is a struggle in the emerging consciousness of Adam and Eve. God had just created and animated the first human with a soul. The very nature of man and woman had been elevated to more closely join in communion with God. However, they retained their serpent-like instinctual drives for pleasure, self-indulgence, and power. These baser drives led Adam and Eve to seek a life separate from the will of God.

This story continues to have relevance for us today. Science, when used for the purposes of achieving the will of God, brings goodness and healing to the earth. Science, when used for the baser purposes of achieving the drive for power, pleasure or self-indulgence, alienates man and woman from God, each other, themselves and the rest of nature. When scientific research divorces itself from the encumbrances of the philosophical, theological, and ethical consequences of its actions, it can become blind to the consequences of its actions on the human condition and the human person.

The Catholic Church stands resolutely against the desecration of human life through the use of embryonic tissue for the purposes of stem cell research. Those persons who support stem cell research often argue that the end justifies the means. They sincerely feel that more good than harm will result from their research. This is an ethical argument known as Utilitarianism. As Catholics, we follow the Natural Law ethic which states that all life is of intrinsic worth and inalienable value. As such, there is no justification for the intentional destruction of a single life so that others may benefit. In addition, the whole of humanity is devalued by a social conscience that regards human life as something that can be quantified and defined by arbitrary parameters, i.e., the embryo is not human until the fetus has reached a certain stage. Other forms of stem cell research that use other types of tissue and do not threaten the sanctity of life are not a concern for the Catholic Church. The source of totipotent cells (cells that can develop into a human) is a human embryo. The source of multipotent cells (cells that can only develop into tissues, i.e., stem cells from bone marrow) is a developed organism. The Catholic Church has no moral concern about the use of multipotent cells but condemns the use of totipotent cells. Outline several reasons for the Church's concern about embryonic stem cell research.

As Catholics, we are called to ask some fundamental questions when faced with the ethical issues posed by modern technologies. Is this procedure life-giving for all involved? Is this dehumanizing? Does this divorce us from our responsibilities to create, nurture and foster life?

Does this degrade the human condition? Can it serve the common good or is it prone to misuse?

Do we know enough to embark on such dangerous quests? Are we prepared to handle all results, both intended and unintended? Are we being responsible stewards of creation or does the procedure gives specific individuals a license to play God?

We as Catholics are free to choose whether we believe in the theory of evolution by special creation. A Catholic perspective would recognize God's providential action in the processes of evolution. In addition, it is our belief that the evolution of the human race was a special act of creation in which the incarnation of a soul fundamentally altered our nature and set us spiritually apart from the rest of creation.

What is it that Catholics hold as being "special" about the creation of human beings? Is it possible to believe in evolution and be a Catholic at the same time? Scientists and others who justify the use of embryos for research argue that human life begins as some time after conception (14 days is often cited). Catholics believe that life begins at conception. Catholics believe that all humans from the moment of conception have certain rights and one of them is the right to life. What dangers do the views of those who favour embryonic cell research pose for society?