Grade 12 Biology

A Foundation for Implementation

Manitoba

GRADE 12 BIOLOGY

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Ce document est disponible en français.

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INTRODUCTION

Background

Grade 12 Biology: A Foundation for Implementation presents student learning outcomes for Grade 12 Biology. These learning outcomes are the same for students in the English, French Immersion, Français, and Senior Years Technology Education Programs, and result from a partnership involving two divisions of Manitoba Education: School Programs Division and Bureau de l'éducation française Division.

> Student learning outcomes are concise descriptions of the knowledge and skills [and attitudes] that students are expected to learn in a course or grade in a subject area (Manitoba Education and Training, *A Foundation for Excellence* 14).

Manitoba's student learning outcomes for Grade 12 Biology are based, in part, on those found within the *Common Framework of Science Learning Outcomes K to 12: Pan-Canadian Protocol for Collaboration on School Curriculum* (Council of Ministers of Education, Canada) and on those developed as components of the 1998 Manitoba Transitional Curricula. The former, commonly referred to as the *Pan-Canadian Science Framework*, was initiated under the Pan-Canadian Protocol for Collaboration on School Curriculum (1995). It was developed by educators from Manitoba, Saskatchewan, Alberta, British Columbia, the Northwest Territories, the Yukon Territory, Ontario, and the Atlantic Provinces.

Grade 12 Biology: A Foundation for Implementation provides the basis for learning, teaching, and assessing biology in Manitoba. This document also serves as a starting point for future development of curriculum support documents, related teacher support materials, learning resources, assessment tools, and professional learning for teachers. This document also complements the *Pan-Canadian Science Framework* by providing support for its implementation, including suggestions for instruction and assessment.

Vision for Scientific Literacy

Factors such as global interdependence, rapid scientific and technological innovation, the need for a sustainable environment, economy, and society, and the pervasiveness of science and technology in daily life reinforce the importance of scientific literacy. Scientifically literate individuals can more effectively interpret information, solve problems, make informed decisions, accommodate change, and achieve new understandings. Science education makes possible the development of the foundations necessary to develop a functional scientific literacy and assists in building stronger futures for Canada's young people.

The *Pan-Canadian Science Framework* and *Grade 12 Biology: A Foundation for Implementation* support and promote an attainable and realistic vision for scientific literacy.

> The *[Pan-Canadian Science Framework]* is guided by the vision that all Canadian students, regardless of gender or cultural background, will have an opportunity to develop scientific literacy. Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them.
>
> Diverse learning experiences based on the *[Pan-Canadian Science Framework]* will provide students with many opportunities to explore, analyze, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment that will affect their personal lives, their careers, and their future (Council of Ministers of Education, Canada 4).

Goals for Canadian Science Education

Several goals promoting the achievement of scientific literacy within Canadian science education were developed as part of the *Pan-Canadian Science Framework*. These goals are addressed through the Manitoba science curricula. It is hoped that science education will

- encourage students at all levels to develop a rational sense of wonder and curiosity about scientific and technological endeavours
- enable students to use science and technology to acquire new knowledge and to solve problems, so they may improve the quality of their own lives and the lives of others
- prepare students to address science-related societal, economic, ethical, and environmental issues critically
- provide students with a proficiency in science that creates opportunities for them to pursue progressively higher levels of advanced study, prepares them for science-related occupations, and engages them in science-related activities appropriate to their interests and abilities
- develop in students of varying aptitudes and interests a knowledge of the wide variety of careers related to science, technology, and support for the natural and human environments

Beliefs about Learning, Teaching, and Assessing Science

To promote a rational, achievable approach to developing scientific literacy among future citizens, it is crucial to recognize how students learn, how science can best be taught, and how learning can be assessed. Students are curious, active learners who have individual interests, abilities, and needs. They come to school with prior knowledge and various personal and cultural experiences that generate a range of attitudes and beliefs about science and life, and connections between these realms.

Students learn most effectively when their study of science is rooted in concrete learning experiences related to a particular context or situation, and applied to their world of experiences, where appropriate. Ideas and understandings that students develop should be progressively extended and reconstructed as students grow in their experiences and in their ability to conceptualize more deeply. Learning involves the process of linking newly constructed understandings with prior knowledge, and then adding new contexts and experiences to current understandings. It is increasingly important that biology educators draw professional attention to how fundamental research in learning theory will affect their efforts in the science classroom.

Changing Emphases in Science

Student learning outcomes in Grade 12 Biology encompass changing emphases in *science education content delivery* and changing emphases to promote *inquiry*, as envisioned in the *National Science Education Standards* (National Research Council 113).

Changing Emphases in Science Education Content Delivery*	
The *National Science Education Standards* envision change throughout the system. The science content standards [or student learning outcomes] encompass the following changes in emphases:	
Less Emphasis On	**More Emphasis On**
Knowing scientific facts and information	Understanding scientific concepts and developing abilities of inquiry
Studying subject matter disciplines (physical, life, earth sciences) for their own sake	Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science
Separating science knowledge and science process	Integrating all aspects of science content
Covering many science topics	Studying a few fundamental science concepts
Implementing inquiry as a set of processes	Implementing inquiry as instructional strategies, abilities, and ideas to be learned

*Source: Reprinted with permission from *National Science Education Standards*, 1996 by the National Academy of Sciences, courtesy of the National Academies Press, Washington, DC.

Changing Emphases to Promote Inquiry*

The *National Science Education Standards* envision change throughout the system. The science content standards [or student learning outcomes] encompass the following changes in emphases:

Less Emphasis On	More Emphasis On
Activities that demonstrate and verify science content	Activities that investigate and analyze science questions
Investigations confined to one class period	Investigations over extended periods of time
Process skills out of context	Process skills in context
Individual process skills such as observation or inference	Using multiple process skills—manipulation, cognitive, procedural
Getting an answer	Using evidence and strategies for developing or revising an explanation
Science as exploration and experiment	Science as argument and explanation
Providing answers to questions about science content	Communicating science explanations
Individuals and groups of students analyzing and synthesizing data without defending a conclusion	Groups of students often analyzing and synthesizing data after defending conclusions
Doing a few investigations in order to leave time to cover large amounts of content	Doing more investigations in order to develop understanding, ability, values of inquiry, and knowledge of science content
Concluding inquiries with the result of the experiment	Applying the results of experiments to scientific arguments and explanations
Management of materials and equipment	Management of ideas and information
Private communication of student ideas and conclusions to teacher	Public communication of student ideas and work to classmates

*Source: Reprinted with permission from *National Science Education Standards*, 1996 by the National Academy of Sciences, courtesy of the National Academies Press, Washington, DC.

Processes That Engage Students in Science Learning

Development of increased scientific literacy is supported by instructional environments that engage students in the following:

- **Science inquiry:** Students are encouraged to converse, ask penetrating questions, and then seek to explore their own constructed explanations alongside scientific explanations through guided research, writing, and planned investigations.
- **Problem solving:** Students apply their acquired expertise and knowledge in novel, often unforeseeable, ways.
- **Decision making:** As students identify rich, large-context problems, questions, or issues related to the life sciences, they pursue new knowledge that will assist them in making informed, rational, defensible decisions.

Through these processes, students discover the significance of science in their lives and come to appreciate the interrelatedness of science, technology, society, and the environment. Each of these processes can be a starting point for science learning, and may encompass the exploration of new ideas, the development of specific investigations, and the application of ideas that are learned.

To achieve the vision of a scientific literacy for all according to personal interests and inclinations, students could become increasingly more engaged in the planning, development, and evaluation of their own learning experiences. They should have opportunities to work cooperatively with other students, to initiate investigations, to communicate their findings, and to complete projects that demonstrate their learning in a personal, although peer-reviewed, manner.

At the beginning of instructional design, teachers and students should identify expected student learning outcomes and establish performance criteria. It is important that these criteria correspond with provincial learning outcomes. This communication between students and teachers helps identify clearly what needs to be accomplished, thereby assisting in the learning process (see the assessment rubrics in Appendix 10).

When students are aware of expected learning outcomes, they will be more focused on their learning, and may be more likely to assess their own progress. Furthermore, they can participate in creating appropriate assessment and evaluation criteria. Assessment methods must be valid, reliable, and fair to students.

NOTES

SECTION 1: MANITOBA FOUNDATIONS FOR SCIENTIFIC LITERACY

MANITOBA FOUNDATIONS FOR SCIENTIFIC LITERACY

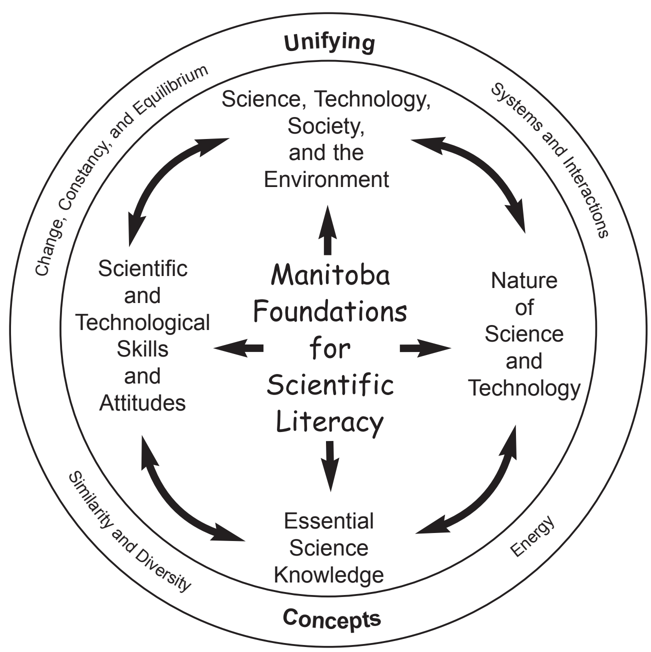
The Five Foundations

To develop scientifically literate students, Manitoba science curricula are built upon five foundations for scientific literacy that have been adapted from the *Pan-Canadian Science Framework* to address the needs of Manitoba students:

- Nature of Science and Technology
- Science, Technology, Society, and the Environment (STSE)
- Scientific and Technological Skills and Attitudes
- Essential Science Knowledge
- Unifying Concepts

The following conceptual organizer illustrates the five foundations for scientific literacy representing the goals of science learning from Kindergarten to Grade 12 in Manitoba.

Manitoba Science Curriculum Conceptual Organizer



These foundations, which are described in more detail on the following pages, have led to the development of the general learning outcomes identified for Grade 12 Biology.

The Nature of Science and Technology

Students learn that science and technology are creative human activities with long histories in all cultures. Science is a way of learning about the universe. This learning stems from curiosity, creativity, imagination, intuition, exploration, observation, replication of experiments, interpretation of evidence, and debate over that evidence and its interpretations. Scientific activity involves predicting, interpreting, and explaining natural and human-made phenomena. Many historians, sociologists, and philosophers of science presently argue that there is no definable, set procedure for conducting a scientific investigation. Rather, they see science as driven by a combination of theoretical concerns, knowledge, experiments, and processes anchored in the physical world.

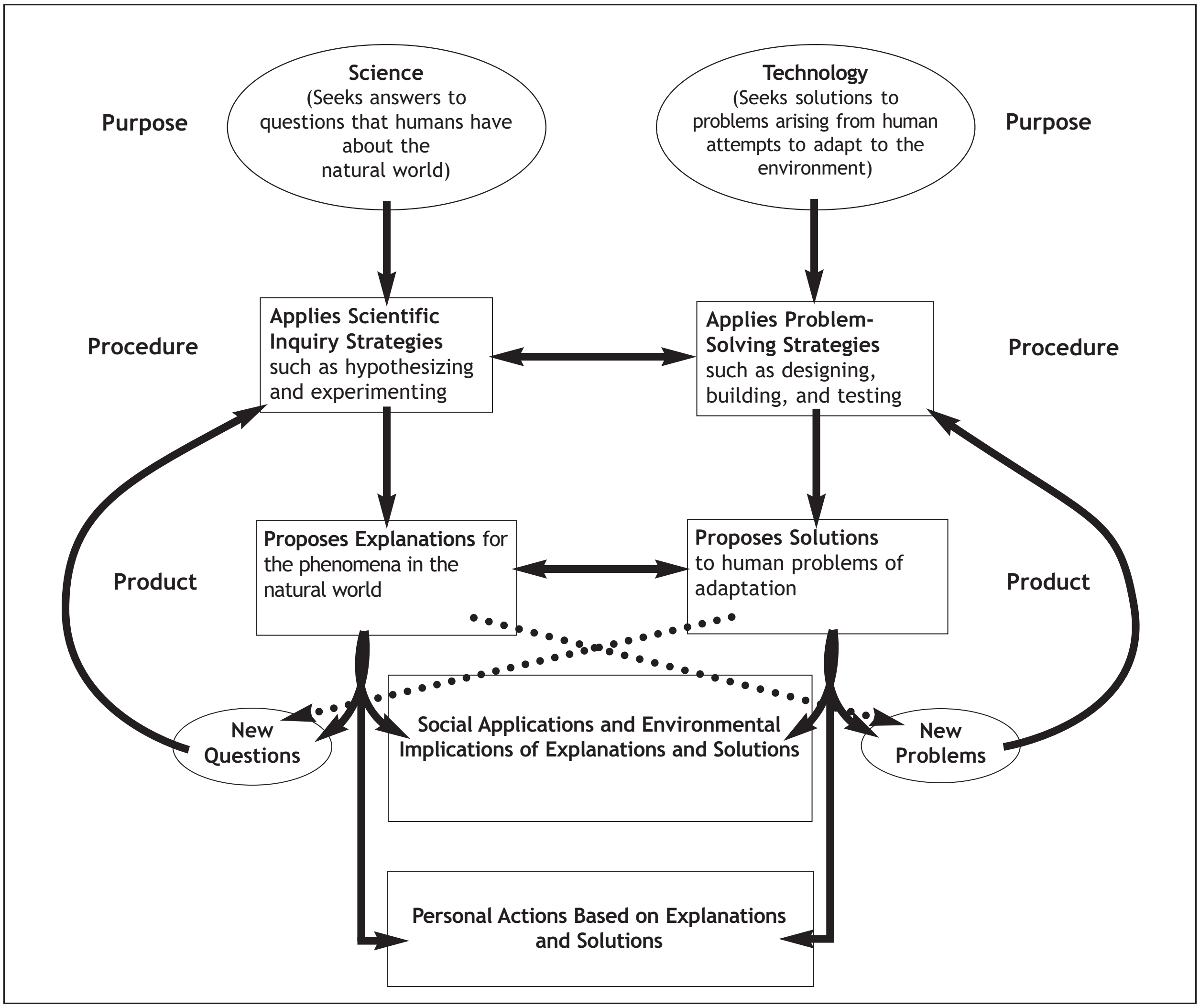
> Producing science knowledge is an intrinsically collective endeavour. There is no such thing as stand-alone science done in isolation. Scientists submit models and solutions for the assessment of their peers, who judge their logical, rational and experimental soundness through reference to the body of existing knowledge and modes of representation (Larochelle and Désautels 235).

Scientific theories are being tested, modified, and refined continually as new knowledge and theories supersede existing knowledge bases. Scientific debate, both on new observations and on hypotheses that challenge accepted knowledge, involves many participants with diverse backgrounds. This highly complex interplay, which has occurred throughout history, is animated by theoretical discussions; experimentation; social, cultural, economic, and political influences; personal biases; and the need for peer recognition and acceptance. Students will realize that while some of our understandings about how the world works are due to revolutionary scientific developments, many of our understandings result from the steady and gradual accumulation of knowledge. History demonstrates, however, that great advances in scientific thought have completely uprooted certain disciplines, transplanting practitioners and theoreticians alike into an entirely new set of guiding assumptions. Such scientific revolutions, as discussed by Thomas S. Kuhn in his influential *The Structure of Scientific Revolutions*, constitute exemplars that can energize the science teaching enterprise, particularly in biology education.

Technology results mainly from proposing solutions to problems arising from human attempts to adapt to the external environment. Technology may be regarded as "a tool or machine; a process, system, environment, epistemology, and ethic; the systematic application of knowledge, materials, tools, and skills to extend human capabilities" (Manitoba Education and Training, *Technology as a Foundation Skill Area* 1). Technology refers to much more than the knowledge and skills related to computers and their applications. Technology is based on the knowledge of concepts and skills from other disciplines (including science), and is the application of this knowledge to meet an identified need or to solve a problem using materials, energy, and tools (including computers). Technology also has an influence on processes and systems, on society, and on the ways people think, perceive, and define their world.

Grade 12 Biology emphasizes both the distinctions and relationships between science and technology. The following illustration shows how science and technology differ in purpose, procedure, and product, while at the same time relating to each other.

Science and Technology: Their Nature and Interrelationships*



*Source: Bybee, Rodger W., et al. *Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction.* Rawley, MA: The NETWORK, Inc., 1989. Adapted with permission.

The following general learning outcomes (GLOs) have been developed to define expectations related to the Nature of Science and Technology foundation area. (For a complete listing of the general and specific learning outcomes, see Appendix 11.)

Nature of Science and Technology General Learning Outcomes

As a result of their Senior Years science education, students will:

A1 Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

A2 Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop.

A3 Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.

A4 Identify and appreciate contributions made by women and men from many societies and cultural backgrounds that have increased our understanding of the world and brought about technological innovations.

A5 Recognize that science and technology interact with and advance one another.

Science, Technology, Society, and the Environment (STSE)

Understanding the complex interrelationships among science, technology, society, and the environment is an essential component of fostering increased scientific literacy. By studying the historical context, students come to appreciate ways in which cultural and intellectual traditions have influenced the questions and methodologies of science, and how science, in turn, has influenced the wider world of ideas.

Today, most scientists work in industry, where projects are more often driven by societal and environmental needs than by pure research. Many technological solutions have evoked complex social and environmental issues. Students recognize the potential of scientific literacy to inform and empower decision making of individuals, communities, and society as a whole.

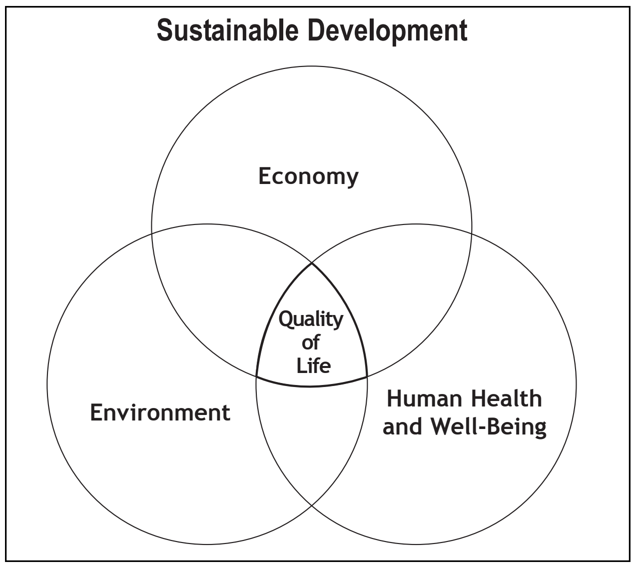
Scientific knowledge is necessary, but not sufficient, for understanding the relationships among science, technology, society, and the environment. To understand these relationships fully, it is essential that students consider the values related to science, technology, society, and the environment.

Sustainable Development as a Decision-Making Model

As a component of achieving scientific literacy, students must also develop an appreciation for the importance of sustainable development. Sustainable development is a decision-making model that considers the needs of both present and future generations, and integrates and balances the *health and well-being of the community*, the *environment*, and the *impact of economic activities*.

- *Sustainable human health and well-being* is characterized by people coexisting harmoniously within local, national, and global communities, and with nature. A sustainable society is one that is physically, psychologically, spiritually, and socially healthy. The well-being of individuals, families, and communities is of considerable importance.

- A *sustainable environment* is one in which the life-sustaining processes and natural resources of the Earth are conserved and regenerated.
- A *sustainable economy* is one that provides equitable access to resources and opportunities. It is characterized by development decisions, policies, and practices that respect cultural realities and differences, and do not exhaust the Earth's resources. A sustainable economy is evident when decisions, policies, and practices are carried out to minimize their impact on the Earth's resources and to maximize the regeneration of the natural environment.
- Decisions or changes related to any one of the three components—human health and well-being, the environment, or the economy—have a significant impact on the other two components and, consequently, on our *quality of life*. Decision making must take into account all three components to ensure an equitable, reasonable, and sustainable quality of life for all.



Educators are encouraged to consult *Education for a Sustainable Future* (Manitoba Education and Training), a document that outlines ways of incorporating precepts, principles, and practices to foster appropriate learning environments that would help direct students toward a sustainable future. The document is available online at <www.edu.gov.mb.ca/k12/docs/support/future/>.

Sustainable Development, Social Responsibility, and Equity

Sustainable development supports principles of social responsibility and equity. This includes equity among nations, within nations, between humans and other species, as well as between present and future generations.

Sustainable development is, at the same time, a decision-making process, a way of thinking, a philosophy, and an ethic. Compromise is an important idea that underlies the decision-making process within a sustainable development approach. In order to achieve the necessary balance among human health and well-being, the environment, and the economy, some compromises will be necessary.

There can be no greater contribution or more essential element to long-term environmental strategies leading to sustainable development that respects the environment . . . than the education of future generations in matters relating to the environment (UNESCO).

Public awareness and understanding of the concept of sustainable development and its practices are essential. If we are to change our way of life we must equip present and future generations with the knowledge and training to put sustainable development into effect (Manitoba Sustainability Development Coordination Unit 19).

As students advance from grade to grade, they identify STSE interrelationships and apply decision-making skills in increasingly demanding contexts, such as the following:

- **Complexity of understanding:** from simple, concrete ideas to abstract ideas; from limited knowledge of science to more in-depth and broader knowledge of science and the world
- **Applications in context:** from contexts that are local and personal to those that are societal and global
- **Consideration of variables and perspectives:** from one or two that are simple to many that are complex
- **Critical judgment:** from simple right or wrong assessments to complex evaluations
- **Decision making:** from decisions based on limited knowledge, made with the teacher's guidance, to decisions based on extensive research that are made independently and involve personal judgment

The following GLOs have been developed to define expectations related to the STSE foundation area.

Science, Technology, Society, and the Environment (STSE) General Learning Outcomes

As a result of their Senior Years science education, students will:

B1 Describe scientific and technological developments—past and present—and appreciate their impact on individuals, societies, and the environment, both locally and globally.

B2 Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and the societal context of the time.

B3 Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.

B4 Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.

B5 Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

Scientific and Technological Skills and Attitudes

A science education that strives for developing scientific literacy must engage students in answering questions, solving problems, and making decisions. These processes are referred to as scientific inquiry, technological problem solving (the design process), and decision making (see the following chart). While the skills and attitudes involved in these processes are not unique to science, they play an important role in the development of scientific understandings and in the application of science and technology to new situations.

Processes for Science Education*

	Scientific Inquiry	Technological Problem Solving (Design Process)	Decision Making
Purpose:	Satisfying curiosity about events and phenomena in the natural world.	Coping with everyday life, practices, and human needs.	Identifying different views or perspectives based on varying information.
Procedure:	What do we know? What do we want to know?	How can we do it? Will it work?	What are the alternatives or consequences? Which choice is best at this time?
Product:	Knowledge about events and phenomena in the natural world.	An effective and efficient way to accomplish a task or meet a need.	A defensible decision in a particular circumstance.

	Scientific Question	Technological Problem	STSE Issue
Example:	Why does my coffee cool so quickly? *An Answer:* Heat energy is transferred by conduction, convection, and radiation to the surrounding environment.	How can I keep my coffee hot? *A Solution:* A foam cup will keep liquids warm for a long time. So will an insulated cup.	Should we use foam cups or ceramic mugs for our meeting? *A Decision:* Since we must use disposable cups for the meeting, we will choose a biodegradable type.

*Source: © Alberta Education, *Integrated Occupational Program, Teacher Resource Manual, Science 8 and 9*, 1989. Adapted with permission.

A description of each of these *processes* follows. *Attitudes*, which are an important element of each process, are also examined, and are treated as indicators along the pathway of student achievement. Hence, attitudes are to be modelled by teachers and students, but are not formally assessed in the same manner as other specific learning outcomes.

Scientific Inquiry

Scientific inquiry is a way of learning about the universe. It involves posing questions and searching for explanations of phenomena. Although no single "scientific method" exists, students require certain skills to participate in science-related experiences using a variety of appropriate methods.

Skills such as questioning, observing, inferring, predicting, measuring, hypothesizing, classifying, designing experiments, and collecting, analyzing, and interpreting data are fundamental to scientific inquiry—as are attitudes such as curiosity, skepticism, and creativity. These skills are often represented as a cycle. This cycle involves posing questions, generating possible explanations, and collecting and analyzing evidence to determine which of these explanations is most useful and accurate in accounting for the phenomena under investigation. New questions may arise to reignite the cycle. It must be noted, however, that many scientific inquiries (past and present) do not necessarily follow a set sequence of steps, nor do they always start at the "beginning" of the cycle; scientists can be creative and responsive to scientific challenges as they arise.

Technological Problem Solving

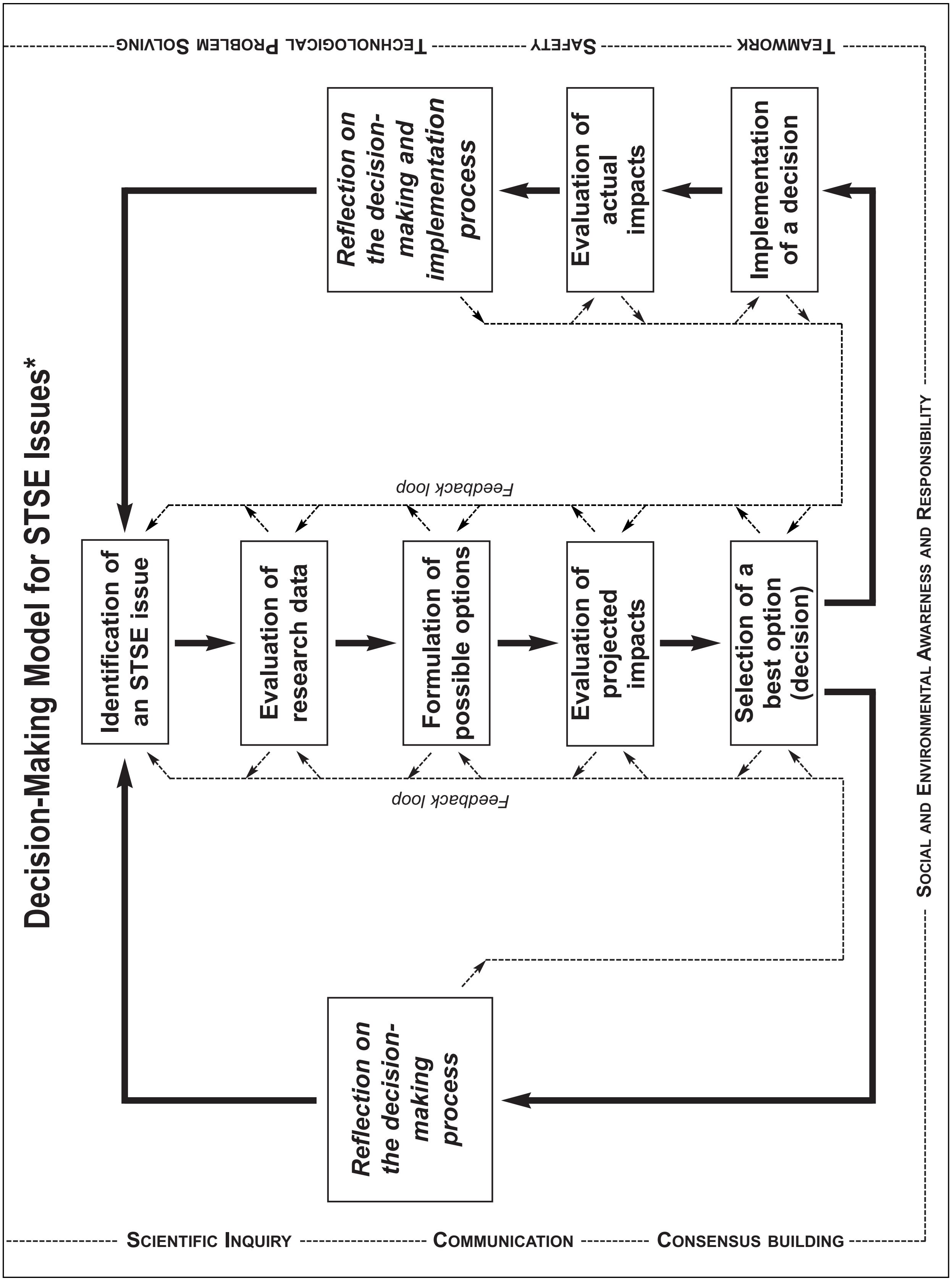
Technological problem solving seeks solutions to problems arising from human attempts to adapt to or change the environment. In Kindergarten to Grade 8 science, students have been developing these skills using a cycle of steps called the *design process.* This design process includes the proposing, creating, and testing of prototypes, products, and techniques in an attempt to reach an optimal solution to a given problem. Feedback and evaluation are built into this cycle. In Senior Years science, these technological problem-solving skills are incorporated into a *decision-making process.*

STSE Issues and Decision Making

Students, as individuals and global citizens, are required to make decisions. Increasingly, the types of issues they face demand an ability to apply scientific and technological knowledge, processes, and products to the decisions they make related to STSE. The decision-making process involves a series of steps, which may include

- clarifying the issue
- critically evaluating all available research
- generating possible courses of action
- making a thoughtful decision
- examining the impact of the decision
- reflecting on the process

Students should be actively involved in decision-making situations as they progress through their science education. Not only are decision-making situations important in their own right, but they also provide a relevant context for engaging in scientific inquiry, problem solving, and the study of STSE relationships (as shown in the following illustration).



*Source: Manitoba Education and Youth. *Senior 2 Science: A Foundation for Implementation.* Winnipeg, MB: Manitoba Education and Youth, 2003. Introduction, p. 12.

Attitudes

Attitudes refer to generalized aspects of behaviour that are modelled for students. Attitudes are not acquired in the same way as skills and knowledge. They cannot be observed at any particular moment, but are evidenced by regular, unprompted manifestations over time. Development of attitudes is a lifelong process that involves the home, the school, the community, and society at large. The development of positive attitudes plays an important role in students' growth, affecting their intellectual development and creating a readiness for responsible application of what they learn.

The following GLOs have been developed to define expectations related to the Scientific and Technological Skills and Attitudes foundation area.

Scientific and Technological Skills and Attitudes General Learning Outcomes

As a result of their Senior Years science education, students will:

C1 Recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations.

C2 Demonstrate appropriate scientific inquiry skills when seeking answers to questions.

C3 Demonstrate appropriate problem-solving skills when seeking solutions to technological challenges.

C4 Demonstrate appropriate critical thinking and decision-making skills when choosing a course of action based on scientific and technological information.

C5 Demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind.

C6 Employ effective communication skills and use information technology to gather and share scientific and technological ideas and data.

C7 Work cooperatively and value the ideas and contributions of others while carrying out scientific and technological activities.

C8 Evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life.

Essential Science Knowledge

The subject matter of science includes theories, models, concepts, and principles that are essential to an understanding of life sciences, physical sciences, and Earth and space sciences. It will be increasingly important for students of biology to make interdisciplinary connections among the following:

- **Life sciences:** This study deals with the growth and interactions of life forms within their environment in ways that reflect their uniqueness, diversity, genetic continuity, and changing nature. Life sciences include the study of organisms (including humans and cells), ecosystems, biodiversity, biochemistry, and biotechnology.

- **Physical sciences:** Primarily associated with chemistry and physics, the physical sciences deal with matter, energy, and forces. Matter has structure, and interactions exist among its components. Energy links matter to gravitational, electromagnetic, and nuclear forces of the universe. The laws of conservation of mass and energy, momentum, and charge are addressed by physical science.
- **Geosciences and the space sciences:** These studies provide students with local, global, and universal perspectives. Earth exhibits form, structure, and patterns of change, as does our surrounding solar system and the physical universe beyond. Earth and space sciences include fields of study such as geology, hydrology, meteorology, and astronomy.

The following GLOs have been developed to define expectations related to the Essential Science Knowledge foundation area.

Essential Science Knowledge General Learning Outcomes

As a result of their Senior Years science education, students will:

D1 Understand essential life structures and processes pertaining to a wide variety of organisms, including humans.

D2 Understand various biotic and abiotic components of ecosystems, as well as their interaction and interdependence within ecosystems and within the biosphere as a whole.

D3 Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

D4 Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts.

D5 Understand the composition of the Earth's atmosphere, hydrosphere, and lithosphere, as well as the processes involved within and among them.

D6 Understand the composition of the universe, the interactions within it, and the implications of humankind's continued attempts to understand and explore it.

The Unifying Concepts

An effective way to create linkages within and among science disciplines is to use unifying concepts—the key ideas that underlie and integrate all science knowledge and extend into areas such as mathematics and social studies. Unifying concepts help students construct a more holistic, systems-related understanding of science and its role in society.

The following four unifying concepts were used in the development of Grade 12 Biology:

- **Similarity and diversity:** The concepts of similarity and diversity provide tools for organizing our experiences with the world. Beginning with informal experiences, students learn to recognize attributes of materials, organisms, and events that help to make useful distinctions between and among them. Over time, students adopt accepted procedures and protocols for describing and classifying objects, organisms, and events they encounter, thus enabling them to share ideas with others and to reflect on their own experiences.

- **Systems and interactions:** An important part of understanding and interpreting the world is the ability to think about the whole in terms of its parts and, alternately, about parts in terms of how they relate to one another and to the whole. A system is a collection of components that interact with one another so that the overall effect is often different from that of the individual parts, even when these are considered together. Students will study both natural and technological systems.
- **Change, constancy, and equilibrium:** The concepts of constancy and change underlie most understandings of the natural and technological world. Through observations, students learn that some characteristics of living things, materials, and systems remain constant over time, whereas others change. Through formal and informal studies, students develop an understanding of the processes and conditions in which change, constancy, and equilibrium take place.
- **Energy:** The concept of energy provides a conceptual understanding that brings together many aspects of natural phenomena, materials, and the processes of change. Energy, whether transmitted or transformed, is the driving force of both movement and change. Students learn to describe energy in terms of its effects and, over time, develop a concept of energy as something inherent within the interactions of materials, the processes of life, and the functions of systems.

The following GLOs have been developed to define expectations related to the Unifying Concepts foundation area.

Unifying Concepts General Learning Outcomes

As a result of their Senior Years science education, students will:

E1 Describe and appreciate the similarity and diversity of forms, functions, and patterns within the natural and constructed world.

E2 Describe and appreciate how the natural and constructed world is made up of systems and how interactions take place within and among these systems.

E3 Recognize that characteristics of materials and systems can remain constant or change over time, and describe the conditions and processes involved.

E4 Recognize that energy, whether transmitted or transformed, is the driving force of both movement and change, and is inherent within materials and in the interactions among them.

Kindergarten to Grade 10 Science and Grade 11 Biology Topic Chart

The following table provides a quick reference to the different thematic clusters for Kindergarten to Grade 10 Science and Grade 11 Biology. It allows teachers to examine, at a glance, students' previous exposure to scientific knowledge in different areas. The biology-related content clusters are grey-shaded for reference.

<table>
<tr><th></th><th>Cluster 0</th><th>Cluster 1</th><th>Cluster 2</th><th>Cluster 3</th><th>Cluster 4</th></tr>
<tr><td>Kindergarten Science</td><td rowspan="15">Overall Skills and Attitudes
(To Be Integrated into Clusters 1 to 4)</td><td>Trees</td><td>Colours</td><td>Paper</td><td>——</td></tr>
<tr><td>Grade 1 Science</td><td>Characteristics and Needs of Living Things</td><td>The Senses</td><td>Characteristics of Objects and Materials</td><td>Daily and Seasonal Changes</td></tr>
<tr><td>Grade 2 Science</td><td>Growth and Changes in Animals</td><td>Properties of Solids, Liquids, and Gases</td><td>Position and Motion</td><td>Air and Water in the Environment</td></tr>
<tr><td>Grade 3 Science</td><td>Growth and Changes in Plants</td><td>Materials and Structures</td><td>Forces That Attract or Repel</td><td>Soils in the Environment</td></tr>
<tr><td>Grade 4 Science</td><td>Habitats and Communities</td><td>Light</td><td>Sound</td><td>Rocks, Minerals, and Erosion</td></tr>
<tr><td>Grade 5 Science</td><td>Maintaining a Healthy Body</td><td>Properties of and Changes in Substances</td><td>Forces and Simple Machines</td><td>Weather</td></tr>
<tr><td>Grade 6 Science</td><td>Diversity of Living Things</td><td>Flight</td><td>Electricity</td><td>Exploring the Solar System</td></tr>
<tr><td>Grade 7 Science</td><td>Interactions within Ecosystems</td><td>Particle Theory of Matter</td><td>Forces and Structures</td><td>Earth's Crust</td></tr>
<tr><td>Grade 8 Science</td><td>Cells and Systems</td><td>Optics</td><td>Fluids</td><td>Water Systems</td></tr>
<tr><td>Grade 9 Science</td><td>Reproduction</td><td>Atoms and Elements</td><td>Nature of Electricity</td><td>Exploring the Universe</td></tr>
<tr><td>Grade 10 Science</td><td>Dynamics of Ecosystems</td><td>Chemistry in Action</td><td>In Motion</td><td>Weather Dynamics</td></tr>
<tr><td rowspan="4">Grade 11 Biology</td><td>Unit 1</td><td>Unit 2</td><td>Unit 3</td><td>Unit 4</td></tr>
<tr><td>Wellness and Homeostasis</td><td>Digestion and Nutrition</td><td>Transportation and Respiration</td><td>Excretion and Waste Management</td></tr>
<tr><td>Unit 5</td><td>Unit 6</td><td></td><td></td></tr>
<tr><td>Protection and Control</td><td>Wellness and Homeostatic Changes</td><td colspan="2"></td></tr>
</table>

NOTES

SECTION 2:
ENHANCING STUDENT LEARNING IN GRADE 12 BIOLOGY

ENHANCING STUDENT LEARNING IN GRADE 12 BIOLOGY

Science and the Learning Process

Students are active learners who have individual interests, abilities, and needs. They come to school with various personal and cultural experiences and prior knowledge that generate a range of attitudes and beliefs about science and life.

Students learn most effectively when they are actively engaged in the learning process. Active learning involves the construction of meaning through the interaction of prior knowledge, motivation, purpose, and new experiences. The process of learning varies from one individual to another, and is shaped by many factors, including personal and social influences. Science learning is more meaningful when students

- discover the significance of science in their lives
- appreciate the interrelatedness of science, technology, society, and the environment

Science *knowledge, skills, and attitudes* are interdependent aspects of learning, and need to be integrated in the learning process. Meaningful learning in science requires both depth and breadth of understanding. To achieve the vision of scientific literacy for all, students should become more engaged in the planning, development, and assessment of their own learning experiences.

The Senior Years Student and the Science Learning Environment

Student learning is central to teachers' work. Teachers make decisions regarding course content, learning materials and resources, and instructional and assessment methods on an ongoing basis. Successful learning is more likely to occur if these decisions are informed by teachers' understanding of their students and the ways they learn.

Teachers seeking to learn about their students need to be knowledgeable in various areas, including the following:

- **How people learn:** In recent decades, cognitive psychology, brain-imaging technology, and multiple intelligences theory have transformed our understanding of learning.
- **Ways in which student populations are changing:** The students teachers encounter today are different in many respects from students a generation ago. Students are more sophisticated in their knowledge and use of information and communication technologies, and much of their understanding of the world comes from electronic media. Classrooms are more likely to be ethnically diverse. Students are more likely to be living with a single parent or stepfamily. More students have part-time jobs.
- **Developmental characteristics of students:** The characteristics of adolescent learners have many implications for teachers.

- **The unique qualities of each student:** Family relationships, academic and life experiences, personality, interests, learning styles, socio-economic status, and rate of development all influence a student's ability to learn. Teachers can gain an understanding of the unique qualities of each student through daily interactions, observations, and assessment.

Characteristics of Grade 12 Learners

For many students, Grade 12 is a stable and productive year. Many Grade 12 students have developed a degree of security within their peer group and a sense of belonging in school. They show increasing maturity in dealing with the freedoms and responsibilities of late adolescence: romantic relationships, part-time jobs, a driver's licence. In Grade 12, most students have a great deal of energy and a growing capacity for abstract and critical thinking. Many are prepared to express themselves with confidence and to take creative and intellectual risks. The stresses and preoccupations of preparing for graduation, post-secondary education, or full-time jobs are still a year away. For many students, Grade 12 may be the most profitable academic year of the Senior Years.

Although many Grade 12 students handle their new responsibilities and the demands on their time with ease, others experience difficulty. External interests may seem more important than school. Because of their increased autonomy, students who previously had problems managing their behaviour at school may now express their difficulties through poor attendance, alcohol and drug use, or other behaviours that place them at risk.

Students struggling to control their lives and circumstances may make choices that seem to teachers to be contrary to the students' best interests. Communication with the home and awareness of what their students are experiencing outside school continue to be important for Grade 12 teachers. Although the developmental variance evident in previous years has narrowed, students in Grade 12 can still change a great deal in the course of one year or even one semester. Grade 12 teachers need to be sensitive to the dynamic classroom atmosphere and recognize when shifts in interests, capabilities, and needs are occurring, so they can adjust learning experiences for their students.

The following chart identifies some common characteristics of late adolescence observed in educational studies (Glatthorn; Maxwell and Meiser; Probst) and by Manitoba teachers, and discusses the implications of these characteristics for teachers.

Grade 12 Learners: Implications for Teachers*	
Characteristics of Grade 12 Learners	**Significance for Grade 12 Teachers**
Cognitive Characteristics	
• Most Grade 12 learners are capable of abstract thought and are in the process of revising their former concrete thinking into a fuller understanding of principles.	• Teach to the big picture. Help students forge links between what they already know and what they are learning. Be cognizant of individual differences and build bridges for students who think concretely.
• Students are less absolute in their reasoning, more able to consider diverse points of view. They recognize that knowledge may be relative to context.	• Focus on developing problem-solving and critical thinking skills, particularly those related to STSE and decision making.
• Many basic learning processes have become automatic by Grade 12, freeing students to concentrate on complex learning.	• Identify the knowledge, skills, and strategies that students already possess, and build the course around new challenges. Through assessment, identify students who have not mastered learning processes at Grade 12 levels and provide additional assistance and support.
• Students have a clearer self-understanding and have developed specialized interests and expertise. They need to connect what they are learning to the world outside the school. Biology must be seen as valuable and necessary.	• Use strategies that enhance students' metacognition. Encourage students to develop scientific skills through exploring areas of interest. Cultivate classroom experts and invite students with individual interests to enrich the learning experience of the class.
Psychological and Emotional Characteristics	
• It is important for Grade 12 students to see that their autonomy and emerging independence are respected. They need a measure of control over what happens to them in school.	• Provide choice. Allow students to select many of the resources they will explore and the forms they will use to demonstrate their learning. Collaborate with students in assessment. Teach students to be independent learners. Gradually release responsibility to students.
• Students are preparing for senior leadership roles within the school and may be more involved with leadership in their communities.	• Provide students with leadership opportunities within the classroom and with a forum to practise skills in public speaking and group facilitation.
• Students need to understand the purpose and relevance of practices, policies, and processes. They may express their growing independence through a general cynicism about authority and institutions.	• Use students' tendency to question social mores to help them develop critical thinking. Negotiate policies and demonstrate a willingness to make compromises. Use students' questions to fuel classroom inquiry.
• Grade 12 students have a clearer sense of identity than they had previously and are capable of being more reflective and self-aware. Some students are more willing to express themselves and disclose their thoughts and ideas.	• Provide optional and gradual opportunities for self-disclosure. Invite students to explore and express themselves through their work. Celebrate student differences.

(continued)

*Source: Manitoba Education and Training. *Senior 4 English Language Arts: A Foundation for Implementation*. Winnipeg, MB: Manitoba Education and Training, 2000. Section 3, pp. 9–11.

Grade 12 Learners: Implications for Teachers (continued)	
Characteristics of Grade 12 Learners	**Significance for Grade 12 Teachers**
Physical Characteristics	
• Many Grade 12 students have reached adult physical stature. Others, particularly males, are still in a stage of extremely rapid growth and experience a changing body image and self-consciousness.	• Be sensitive to the risk students may feel in public performances and increase expectations gradually. Provide students with positive information about themselves.
• By Grade 12, students are better able to sit still and concentrate on one learning task for longer periods, but they still need interaction and variety. They have a great deal of energy.	• Put physical energy to the service of active learning instead of trying to contain it. Provide variety; change the pace frequently; use kinesthetic learning experiences.
• Grade 12 students still need more sleep than adults do, and may come to school tired as a result of part-time jobs or activity overload.	• Be aware that inertia or indifference may be the result of fatigue. Work with students and families to set goals and plan activities realistically so that school work assumes a higher priority.
Moral and Ethical Characteristics	
• Grade 12 students are working at developing a personal ethic, rather than following a prescribed set of values and code of behaviour.	• Explore the ethical meaning of situations in life and in scientific contexts. Provide opportunities for students to reflect on their thoughts in discussion, writing, or representation.
• Students are sensitive to personal or systemic injustice but are increasingly realistic about the factors affecting social change.	• Explore ways in which decision-making activities can effect social change, and link to the continuum of science, technology, society, and the environment.
• Students are shifting from an egocentric view of the world to one centred in relationships and community. They are able to recognize different points of view and adapt to difficult situations.	• Provide opportunities for students to make and follow through on commitments and to refine their interactive skills.
• Students are becoming realistic about the complexities of adult responsibilities but resist arbitrary authority.	• Explain the purpose of every learning experience. Enlist student collaboration in developing classroom policies. Strive to be consistent.

(continued)

Grade 12 Learners: Implications for Teachers (continued)	
Characteristics of Grade 12 Learners	**Significance for Grade 12 Teachers**
Social Characteristics	
• By Grade 12, certain individuals will take risks in asserting an individual identity. Many students, however, continue to be intensely concerned with how peers view their appearance and behaviour. Much of their sense of self is drawn from peers, with whom they may adopt a “group consciousness,” rather than from making autonomous decisions.	• Ensure that the classroom has an accepting climate. Model respect for each student. Use learning experiences that foster student self-understanding and self-reflection. Challenge students to make personal judgments about situations in life and in their natural environment.
• Adolescents frequently express identification with peer groups through slang, musical choices, clothing, body decoration, and behaviour.	• Foster a classroom identity and culture. Ensure that every student is included and valued. Structure learning so that students can interact with peers, and teach strategies for effective interaction.
• Crises of friendship and romance, and a preoccupation with relationships, can distract students from academics.	• Open doors for students to study personal relationships in science (for example, through biographies of scientists). Respect confidentiality, except where a student’s safety is at risk.
• Students begin to recognize teachers as individuals and welcome a personal connection.	• Nurture and enjoy a relationship with each student. Try to find areas of common interest with each one. Respond with openness, empathy, and warmth.

Student Engagement

The concept of student engagement and its relationship to learning and achievement has become increasingly prominent in educational research and literature in recent years. While there are a number of definitions of student engagement, most contain behavioural, cognitive, and affective dimensions. The *behavioural dimension* refers to student actions related to engagement, such as participating in classroom and school activities, and accepting responsibility for their learning and assignments. The *cognitive dimension* includes student understandings about their own learning—for example, metacognition, and engaging in self-reflection and self-assessment. Student feelings about school, such as developing positive attitudes to school and school subjects, and demonstrating an interest in their learning are part of the *affective dimension*.

Research suggests that when learning activities are more student-directed than teacher-directed and the learning tasks are authentic, involving students in challenging and meaningful inquiry to solve real-life problems, students are more likely to develop positive emotions in the classroom and to become engaged in their learning (Shernoff et al). Greater engagement in classroom activities in high school is a significant predictor of continuing student motivation and commitment, increases the likelihood of successful school completion, and is critical to students’ capacity to be lifelong learners (Levin; Shernoff et al).

Creating a Stimulating Learning Environment

A vital science class grows out of, and is reflected in, a stimulating and inviting learning environment. Teachers develop a positive learning environment by attending to both physical and non-physical components.

Physical components of a positive learning environment may include the following:

- seating arrangements that reflect a student-centred philosophy and that facilitate flexible student groupings
- a classroom library, including science periodicals, newspaper articles, science fiction, files of previous tests and examinations, exemplars or samples of student work (such as projects, lab reports, and posters), reference materials (including dictionaries and encyclopedias of science), and software and CD-ROM titles
- access to electronic media equipment, including overhead/LCD projector, computer with Internet access, television, DVD player/VCR, digital camera/video recorder, and microcomputer-based laboratory (MBL) probeware or calculator-based laboratory (CBL) probeware
- posters, displays, charts, diagrams, plants, animals, fossils, models, and pictures reflecting and displaying student work and stimulating student interest in the current learning focus
- posters, diagrams, and flow charts of learning processes and strategies to encourage students' independent and small-group learning
- regular access to a well-equipped and safe science laboratory to foster the development of lab skills
- student input in classroom design and displays

Non-physical components (Cotton; Marzano; Stronge; Cooper) assist teachers in building a positive learning community and may include the following:

- belief that all students are equally important in the classroom and that each student has unique qualities that contribute to the classroom learning community
- communicating interest in and attention to student interests, problems, and accomplishments
- encouragement of student efforts and development of a sense of responsibility and self-reliance
- high standards of learning for all students and provision of time, instruction, and encouragement for all learners
- development of a safe, risk-free learning environment where failure to meet expectations is not penalized but is an opportunity for improving performance
- student-centred, hands-on learning strategies where students pursue learning with the assistance of the teacher, including student collaboration and cooperation
- definition and recognition of excellence in terms of learning outcomes (criterion-referenced) rather than peer comparisons (norm-referenced)

- clear and focused instruction by providing discussion of learning outcomes and culminating assessment tasks, connections between lessons and larger concepts, and opportunities for guided and independent practice
- frequent descriptive feedback, on both in-class work and assignments, and collaboration with students in developing action plans for success

Planning with the End in Mind

Much of the educational research and literature today is focused on classroom-based assessment. Assessment has a profound impact on student motivation and self-esteem, both of which are critical influences on student learning. Wiggins and McTighe promote a backward design model in which plans for both assessment and instruction stem from a clear understanding of the learning outcomes and the criteria for success that is communicated between the teacher and students. When planning lessons and units, teachers must have a clear conception of the learning outcomes. Then, instruction, assessment, and communication are focused on the learning outcomes (Manitoba Education, Citizenship and Youth, *Communicating Student Learning*).

Wiggins and McTighe suggest the following sequence for planning:

1. Identify the desired results.
2. Determine acceptable evidence.
3. Plan learning experiences and instruction.

When planning with the end in mind, teachers first identify the learning outcomes to be addressed in a given unit or learning experience. Decisions must be made as to what students are to learn. By clarifying the learning goals, teachers are able to focus their instruction and assessment on assisting students to achieve the desired results.

Next, teachers design the culminating summative assessment tasks through which students will demonstrate evidence that they have mastered the learning outcomes. These tasks are planned and communicated to students in advance of their learning so that students have a clear understanding of the learning goals, and the products and performances by which they will demonstrate achievement of their learning. This helps students stay focused on their learning.

Once the learning outcomes are identified and the culminating tasks are designed, teachers can plan the learning experiences. Instruction and formative assessments are developed to prepare students for the culminating tasks. The learning experiences are designed to enable students to build and to practise what they need to demonstrate in the culminating tasks to provide evidence of their learning.

Planning Considerations

Grade 12 Biology is driven by specific learning outcomes arranged around the key themes of *genetics* and *biodiversity*. Working with "big ideas" such as these can stimulate student interest and allow for more in-depth inquiry. Biology curricula in the past have focused primarily on presenting a large amount of content deemed essential. While the Grade 12 Biology curriculum continues to be concerned with students gaining the relevant knowledge, it is also concerned with fostering the development of skills (process skills, critical thinking skills, independent learning skills) and attitudes (respect, appreciation, reflection).

CT

A culminating task is designed to integrate several learning outcomes and skills and attitudes outcomes of a unit into one major assignment. The culminating tasks show how theories and concepts are applied in the real world, engage students in problem solving and decision making, and demand innovation and creativity on the part of the student (Cooper). One example of a culminating task is provided in the suggestions for instruction and assessment in each unit of the course. The culminating tasks are identified with the CT graphic shown on the left.

This curriculum design empowers teachers to plan appropriate learning experiences based on the nature of their students, school, and community. Teachers are encouraged to seek their own instructional design with the new curriculum, to share approaches with colleagues, and to use their ideas to develop and extend student experiences and understandings in new ways.

Grade 12 Biology assumes 110 hours of instructional time (including assessment).

Scaffolding and Transfer of Responsibility for Student Learning

Just as scaffolds provide support to a building under construction, scaffolding supports student learning. By providing temporary assistance or frameworks for learning (e.g., graphic organizers, group work), teachers bridge the gap between what students are able to do with the support of others and what they are able to do independently. The scaffolding helps students to advance from their current abilities to the intended goal, and is gradually removed as the students progress.

Associated with scaffolding is the gradual transfer of responsibility for learning. Initially, the teacher takes on most of the responsibility for structuring and leading the learning task, and provides a great deal of guidance to the students. As students' understanding develops, they assume more responsibility for the task by asking questions and attempting more complex applications with greater autonomy (Good and Brophy). The teacher continues to provide coaching and help to students when needed, but steadily reduces the assistance as students' expertise develops. This gradual transfer of responsibility for learning from the teacher to the students helps students to build their confidence by permitting them to demonstrate their growing competence and increases their ability to become independent, self-regulated learners (Frey, Fisher, and Everlove).

Learning Resources

Traditionally, the approach to teaching science in the Senior Years has largely been textbook-based. Research suggests that we should move beyond a single textbook approach and provide students with a variety of information sources. These include human resources, print media, electronic media, field trips, and simulations.

Resource-based learning is a student-centred approach that adapts to student needs, interests, abilities, learning styles, and prior knowledge. An environment that is rich in resources allows students to explore and discover as they learn, and to make personal learning choices that are relevant and meaningful.

As our society continues to change, so do the roles of teachers and learners. A more flexible model of the teaching-learning process in which teachers facilitate the learning process and students make decisions and assume responsibility for their learning is becoming more prevalent in our schools. A resource-based learning approach helps students manage the information overload that typifies today's society, and teaches them how to continue their learning outside the school setting. While the development of fundamental knowledge is still essential in science, students also need the skills to locate, access, and evaluate pertinent information.

For more information on selecting learning resources for Grades 11 and 12 Biology, see the Manitoba Education website at
<www.edu.gov.mb.ca/k12/learnres/bibliographies.html>.

Diversity in the Classroom

Students come from a variety of backgrounds and have distinct learning needs, learning and thinking styles, and prior knowledge and experiences. Their depth of prior knowledge varies, reflecting their experiences inside and outside the classroom. For new learning to occur, it is important for teachers to activate students' prior knowledge, to correct misconceptions, and to encourage students to relate new information to prior experiences.

As a result of Manitoba's cultural diversity, students bring a variety of socially constructed meanings, references, and values to science learning experiences, as well as their unique learning approaches. In addition, cultural influences can affect how students think about science: reasoning by analogy or by strict linear logic; memorization of specific correct responses or generalizations; problem solving by induction or deduction; or needing to learn through hands-on experiences to gain one aspect of a skill before moving on to the next step (Kolodny). Cultural norms vary among societies; for example, values that discourage assertiveness, outspokenness, and competitiveness in some cultures can result in behaviour that may be interpreted in another culture as being indifferent, having nothing to say, or being unable to act decisively (Hoy; National Research Council). As noted in *Senior Years Science Teachers' Handbook*, "to be effective, the classroom must reflect, accommodate, and embrace the cultural diversity of its students" (Manitoba Education and Training 7.13).

Ethical Issues

A fundamental aspect of science learning and teaching (at all grades, but particularly in the Senior Years) is the consideration of controversial issues—issues that involve ethics, principles, beliefs, and values. For example, the technological application of biological principles in areas such as genetic engineering and human reproductive and medical technologies raises questions of ethics and values. Teachers should not avoid controversial issues, as discussion and debate concerning ethical questions serve to motivate students and make learning more personally meaningful.

Students should understand that science provides the background for informed personal and social decisions, and that as informed decision makers, they may have an impact on society and the world. Some students and parents may express concern because the perspectives of science conflict with personal systems of belief. These individuals have a right to expect that science and the public education system will respect those beliefs, although this does not preclude such issues from arising in the classroom. Teachers should explain that science is one way of learning about the universe and our place in it, and that other explanations have been put forth.

Dealing with Controversial Issues

The following guidelines may assist teachers in dealing with controversial issues in the classroom:

- Approach all issues with sensitivity.
- Clearly define the issues.
- Establish a clear purpose for discussions.
- Establish parameters for discussions.
- Ensure that the issues do not become personalized or directed at individual students.
- Protect the interests of individual students by finding out in advance whether any student would be personally affected by the discussion.
- Exercise flexibility by permitting students to choose alternative assignments.
- Accept the fact that there may not be a single "right answer" to a question or issue.
- Respect every student's right to voice opinions or perspectives.
- Help students clarify the distinction between informed opinion and bias.
- Help students seek sufficient and reliable information to support various perspectives.
- Allow time to present all relevant perspectives fairly and to reflect upon their validity.

The Responsible Use of Animals in the Biology Classroom

Biology teachers are encouraged to foster a respect for life and teach about the interrelationships among and interdependency of all living things. Furthermore, a stewardship approach emphasizes that humans must care for the fragile web of life that exists on our planet.

The use of live animals and the dissection of animals is a well-established practice in the teaching of life sciences. Well-constructed learning activities can illustrate important and enduring biological principles. Teachers must, however, carefully consider the educational objectives and available alternatives before using animals in the classroom. Justification on the grounds that "we have always done this" is unacceptable.

Grade 12 Biology does not mandate that dissection (either real or virtual) take place in the classroom. Dissection is one of many instructional strategies that may be used to familiarize students with the structure and function of organs and organ systems. Interactive multimedia materials such as computer simulations, tutorials, and video clips can substitute for the use of animals in the classroom. However, these alternatives must satisfy the objectives of teaching scientific methodology and fundamental biological concepts. If, in the judgment of the teacher, available alternatives do not meet these objectives, dissection may be used, provided that no student is forced to participate in a dissection over his or her objections. In the event that a student chooses not to participate in a dissection, he or she should be provided with an alternate activity of comparable complexity and rigour.

Implementing alternative methods does not mean excluding animals from the classroom. Classroom pets stimulate student interest in the life sciences, and their care can foster a respect for life. Certain instructional strategies allow for the continued use of animals, but with a modified approach. For example, observations of vertebrates in behaviour studies, and experimentation with invertebrates (e.g., fruit flies, planarians) can be used to illustrate important biological principles. In these cases, prudent and responsible use of these animals is essential.

Instruction

Science learning can be enhanced by using a variety of settings both in and outside the school, flexible student groupings, and numerous other instructional strategies.

Active Learning

Well-balanced science programming includes individual, collaborative, and teacher-directed learning experiences and provides students with a variety of conceptual tools and advance organizers.

Effective science instruction includes the use of strategies that promote student inquiry and interaction. These strategies include cooperative and peer learning, laboratory activities, project-based learning, teacher- and student-initiated inquiry, and research.

It is through guided inquiry and interaction that students construct meaning from their individual experiences. Students require opportunities to engage in authentic and relevant scientific issues and events. It is important that these experiences be integral to science learning.

Active learning is encouraged through resource-based and experiential learning. These include laboratory activities, field studies, and the use of information and communication technologies. Effective practices in science actively engage students in scientific inquiry processes such as research, problem solving, and decision making.

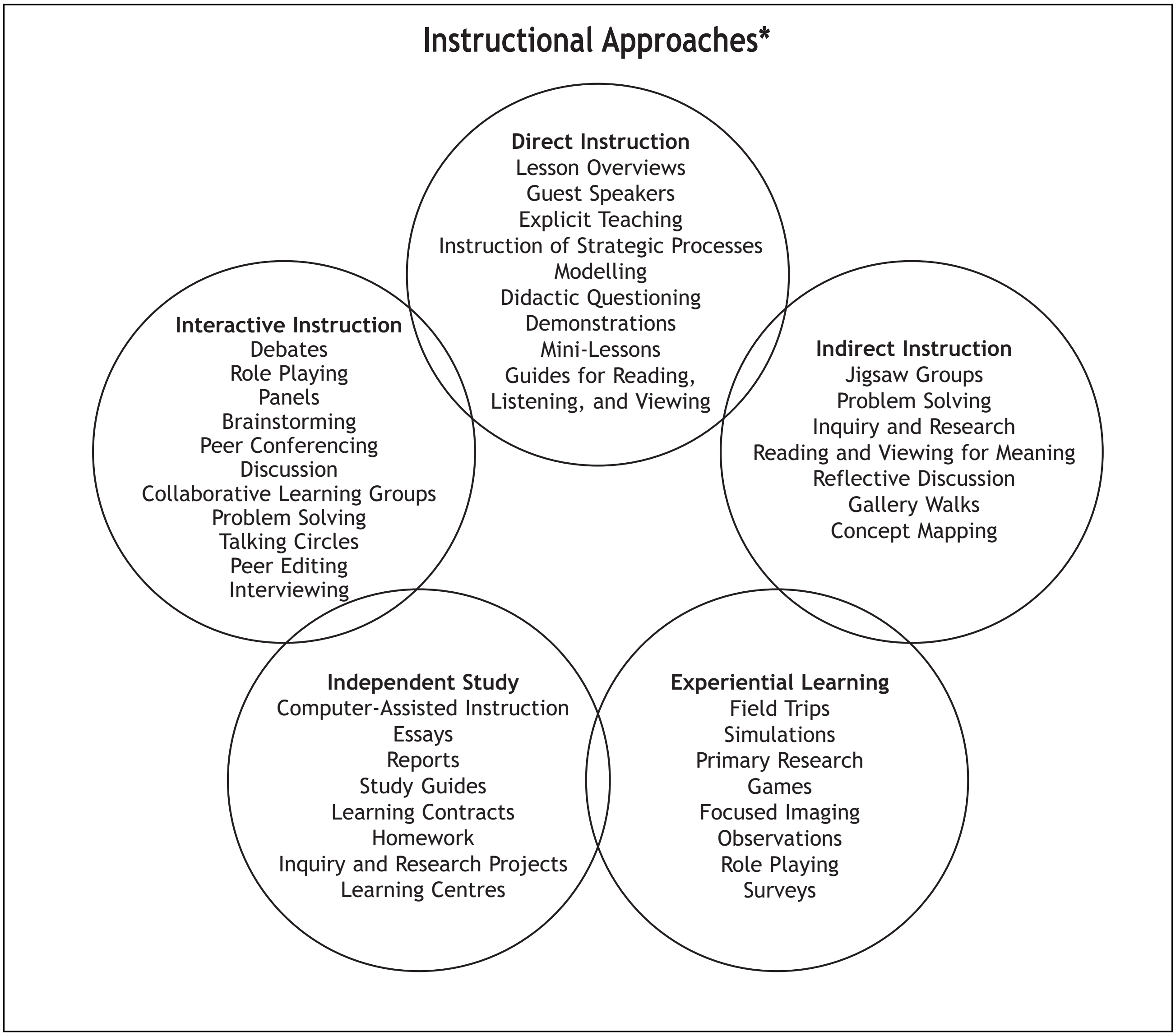
Instructional Approaches

In planning learning experiences, teachers can chose from a variety of instructional approaches and methods and use these in various combinations.

Instructional approaches may be categorized as

- direct instruction
- indirect instruction
- experiential learning
- independent study
- interactive instruction

The following diagram displays these instructional approaches and suggests some examples of methods within each approach. Note that the approaches overlap.



*Source: © 1991, Government of Saskatchewan. Adapted with permission.

Teachers consider a number of factors as they select and adapt instructional approaches and methods:

- Will the approach meet the unique learning styles of students?
- Will it assist students in achieving the targeted learning outcomes?
- Will it engage them?
- Do student have the prerequisite knowledge of the content and/or skills to enable them to learn with this approach?
- What are the advantages and disadvantages of this approach?

Some of these considerations are included in the following chart.

Instructional Approaches: Roles, Purposes, and Methods*

Instructional Approaches	Roles	Purposes/Uses	Methods	Advantages/ Limitations
Direct Instruction	• Highly teacher-directed • Teacher uses didactic questioning to elicit student involvement	• Providing information • Developing step-by-step skills and strategies • Introducing other approaches and methods • Teaching active listening and note making	Teachers: • Explicit teaching • Lesson overviews • Guest speakers • Instruction of strategic processes • Lecturing • Didactic questioning • Demonstrating and modelling prior to guided practice • Mini-lessons • Guides for reading, listening, and viewing	• Effective in providing students with knowledge of steps of highly sequenced skills and strategies • Limited use in developing abilities, processes, and attitudes for critical thinking and interpersonal learning • May encourage passive, not active learning
Indirect Instruction	• Mainly student-centred • Teacher's role shifts to facilitator, supporter, resource person • Teacher monitors progress to determine when intervention or another approach is required	• Activating student interest and curiosity • Developing creativity and interpersonal skills and strategies • Exploring diverse possibilities • Forming hypotheses and developing concepts • Solving problems • Drawing inferences	Students: • Observing • Investigating • Inquiring and researching • Jigsaw groups • Problem solving • Reading and viewing for meaning • Reflective discussion • Concept mapping	• Active involvement is an effective way for students to learn • High degree of differentiation and pursuit of individual interests possible • Excellent facilitation and organizational skills required of teachers • Some difficulty integrating focused instruction and concepts of content

(continued)

*Source: Manitoba Education and Training. *Senior 3 English Language Arts: A Foundation for Implementation*. Winnipeg, MB: Manitoba Education and Training, 1999. Section 2, pp. 5–6.

Instructional Approaches: Roles, Purposes, and Methods (continued)				
Instructional Approaches	**Roles**	**Purposes/Uses**	**Methods**	**Advantages/ Limitations**
Interactive Instruction	• Student-centred • Teacher forms groups, teaches and guides small-group skills and strategies	• Activating student interest and curiosity • Developing creativity and interpersonal skills and strategies • Exploring diverse possibilities • Forming hypotheses and developing concepts • Solving problems • Drawing inferences	Students participating in: • Discussions • Sharing • Generating alternative ways of thinking and feeling • Decision making • Debates • Role-playing • Panels • Brainstorming • Peer conferencing • Collaborative learning groups • Problem solving • Talking circles • Interviewing • Peer editing	• Increase of student motivation and learning through active involvement in groups • Key to success is teacher's knowledge and skill in forming groups, instructing, and guiding group dynamics • Effective in assisting students' development of life skills in cooperation and collaboration
Experiential Instruction	• Student-centred • Teacher's role may be to design the order and steps of the process	• Focusing on processes of learning rather than on products • Developing students' knowledge and experience • Preparing students for direct instruction	Students participating in: • Learning activities • Field trips • Simulations • Primary research • Games • Focused imaging • Role-playing • Surveys • Sharing observations and reflections • Reflecting critically on experiences • Developing hypotheses and generalizations in new situations	• Increase in student understanding and retention • Additional resources and time required for hands-on learning
Independent Study	• Student-centred • Teacher's role to guide or supervise students' independent study, teach knowledge, skills, and strategies that students require for independent learning, and provide adequate practice	• Accessing and developing student initiative • Developing student responsibility • Developing self-reliance and independence	Students participating in: • Inquiry and research projects • Using a variety of approaches and methods • Computer-assisted instruction • Essays and reports • Study guides • Learning contracts • Homework • Learning centres	• Students grow as independent, lifelong learners • Student maturity, knowledge, skills, and strategies important to success • Student access to resources essential • Approach flexible (may be used with individual students while other students use other approaches)

Phases of Learning*

Teachers find the following three phases of learning helpful when planning learning experiences:

- activating (preparing for learning)
- acquiring (integrating and processing learning)
- applying (consolidating learning)

The instructional strategies suggested in this document are organized into activating and acquiring/applying strategies. While these phases are not entirely linear, they are useful for thinking about and planning learning experiences. A variety of activating, acquiring, and applying strategies are discussed in *Senior Years Science Teachers' Handbook* and *Success for All Learners: A Handbook on Differentiating Instruction* (Manitoba Education and Training).

Activating (Preparing for Learning)

One of the strongest indications of how well students will comprehend new information is their prior knowledge of the subject. Some educators observe that more learning occurs during this activating phase than at any other time. In planning instruction and assessment, teachers develop student learning experiences and select strategies for activating their students' prior knowledge. Using these activating strategies, the learning experiences then provide information about the extent of students' prior knowledge of the topic to be studied, their knowledge of and familiarity with the context in which that knowledge was acquired, and their knowledge of and proficiency in applying skills for learning.

Learning experiences that draw on students' prior knowledge

- help students relate new information, skills, and strategies to what they already know and can do (e.g., if a text includes unfamiliar vocabulary, students may not recognize the connection between what they know and the new material being presented)
- allow teachers to recognize misconceptions that might make learning difficult for students
- allow teachers to augment and strengthen students' knowledge base when students do not possess adequate prior knowledge and experience to engage with new information and ideas
- help students recognize gaps in their knowledge
- stimulate curiosity and initiate the inquiry process that will direct learning

This document contains numerous strategies for activating students' prior knowledge, such as brainstorming, KWL (Know, Want to Know, Learned) guides, demonstrations, and questions to stimulate class discussions.

*Source: Manitoba Education and Training. *Senior 3 English Language Arts: A Foundation for Implementation*. Winnipeg, MB: Manitoba Education and Training, 1999. Section 2, pp. 6–8.

Acquiring (Integrating and Processing Learning)

In the second phase of learning, students engage with new information and integrate it with what they already know, adding to and revising their previous knowledge. Part of the teacher's role in this phase is to present this new information or to help students access it from various resources.

Since learning is an internal process, facilitating learning requires more of teachers than simply presenting information. In the acquiring phase, teachers instruct students in strategies that help them make meaning of information, integrate it with what they already know, and express their new understanding. In addition, teachers monitor these processes to ensure that learning is taking place, using a variety of instruments, tools, and strategies such as observations, conferences, and examination of student work.

In practice, within an actual lesson or unit, the acquiring phase of learning may include a series of steps and strategies, such as

- setting the purpose (e.g., discrepant events, lesson overviews, learning logs, Admit Slips)
- presenting information (e.g., demonstrations, guest speakers, mini-lessons, active reading)
- processing information (e.g., note making, group discussions, journals, visual representations)
- modelling (e.g., role-playing, demonstrations)
- checking for understanding (e.g., quizzes, informal conferences)
- practising (e.g., guided practice, rehearsals)

Applying (Consolidating Learning)

New learning that is not reinforced is soon forgotten. The products and performances by which students demonstrate new learning are not simply required for assessment; they have an essential instructional purpose in providing students with opportunities to demonstrate and consolidate their new knowledge, skills and strategies, and attitudes. Students also need opportunities to reflect on what they have learned and to consider how new learning applies to new situations. By restructuring information, expressing new ideas in another form, or integrating what they have learned in science with concepts from other subject areas, students strengthen and extend their learning.

To ensure that students consolidate new learning, teachers plan various learning experiences involving

- reflection (e.g., journals, Exit Slips)
- closure (e.g., sharing of products, debriefing on processes)
- application (e.g., inquiry, design process, decision making)

Differentiating Instruction

How can Senior Years science teachers meet each student's learning requirements and still make learning experiences challenging and meaningful for all? One way to help all students achieve the identified learning outcomes is to differentiate the instructional strategies.

Through differentiating instruction, teachers can

- activate students' prior knowledge
- accommodate multiple intelligences and the variety of learning and thinking approaches
- help students interpret, apply, and integrate information
- facilitate the transfer of knowledge, skills and strategies, and attitudes to students' daily lives
- challenge students to realize academic and personal progress and achievement

Differentiating instruction does not mean offering different programming to each student. Classroom experiences can be differentiated by offering students choices and by varying instructional and assessment strategies to provide challenging and effective learning experiences for all. Ideas for differentiating instruction are provided in *Senior Years Science Teachers' Handbook* and in *Success for All Learners: A Handbook on Differentiating Instruction* (Manitoba Education and Training).

Assessment

Assessment is integral to instruction and learning. It plays a major role in how students learn, their motivation to learn, and how teachers teach.

Purposes of Assessment

Research indicates that ongoing formative assessment contributes more significantly to learning than the traditional focus on summative assessment (Black and Wiliam). Manitoba Education refers to formative assessment as assessment *for* learning and assessment *as* learning.

Each type of assessment serves a purpose and contributes to student success:

- **Assessment *for* learning** helps teachers to gain insight into what students understand so that they can appropriately plan and differentiate teaching strategies and learning opportunities to help students progress. Students need frequent opportunities to obtain meaningful and relevant feedback. Descriptive feedback that includes analytical questions and constructive comments provides information to students that they may use to adjust their learning processes, and is more helpful to students than a numeric or alphabetic grade.
- **Assessment *as* learning** helps students to develop an awareness of how they learn and to use that awareness to adjust and advance their learning, taking an increased responsibility for their learning. When students have the opportunity to become reflective learners they can synthesize their learning, solve problems, apply their learning in authentic situations, and better understand their learning processes.

- **Assessment *of* learning** serves to confirm whether or not students have met curricular outcomes, and provides evidence of achievement to students, teachers, and parents, as well as to the broader educational community. Assessment *of* learning supports learning when it is used to celebrate success, adjust future instruction, and provide feedback to the learner.

Assessment must be planned with its purpose in mind. Assessment *for*, *as*, and *of* learning all have a role to play in supporting and improving student learning, and must be appropriately balanced. The most important part of assessment is the interpretation and use of the information that is gleaned for its intended purpose.

For more information on assessment, consult *Rethinking Classroom Assessment with Purpose in Mind: Assessment for Learning, Assessment as Learning, Assessment of Learning* (Manitoba Education, Citizenship and Youth).

Assessment in the Phases of Learning

Assessment takes place in each of the three phases of learning (activating, acquiring, and applying) and benefits both students and teachers at each phase.

Assessment at Different Phases of Learning*		
	Students	**Teachers**
Activating Phase	Assessment in the activation stage helps **students** • "set the stage" and mentally plan and prepare for new learning • identify the focus of new learning • identify what they already know about a topic • gain interest in a new topic	Assessment in the activation stage helps **teachers** • identify gaps, strengths, misconceptions, and faulty information in students' prior knowledge • identify student interests • provide a focus for planning instructional strategies and the selection of student learning resources • determine which instructional approaches or resources need to be implemented or adapted
Acquiring Phase	Assessment during the acquisition stage helps **students** • become aware of the progress and the degree of understanding they are achieving • experience and adapt different approaches and strategies that facilitate their learning • identify what further learning they need to undertake • improve as they practise	Assessment during the acquisition stage helps **teachers** • revise learning strategies to meet evolving student needs • monitor student growth and progress, and determine whether students are achieving specific learning outcomes (SLOs) • determine if individual students need additional support or further learning opportunities to achieve SLOs • identify which learning outcomes need to be the focus of subsequent instruction and assessment • gather evidence of student growth, which may be used for reporting
Applying Phase	Assessment during the application stage helps **students** • become aware of their growth and achievement, and celebrate their successes • identify their strengths, as well as areas needing further growth • deepen their understandings as they make connections and reflect on their learning, and apply new ideas in meaningful and authentic ways	Assessment during the application stage helps **teachers** • be fully aware of student understanding and achievement of learning outcomes • identify student strengths and areas needing further learning • provide evidence of student growth and achievement for reporting to parents and administrators • reflect on their teaching practices in order to identify changes and revisions to learning strategies

*Source: Manitoba Education, Citizenship and Youth. *Grade 9 Social Studies: Canada in the Contemporary World: A Foundation for Implementation*. Winnipeg, MB: Manitoba Education, Citizenship and Youth, 2007. Overview, p. 43.

Congruence of Assessment with Learning

There are three types of learning outcomes in science—knowledge, skills, and attitudes—and assessment needs to be congruent with each type of learning.

- **Knowledge:** Science places significant emphasis on the acquisition of knowledge. Students do not gain true understanding of science or meet the goal of scientific literacy if they simply memorize and recall facts. Students must be encouraged to use the knowledge they acquire to synthesize and apply new understandings and to demonstrate evidence of their learning.
- **Skills:** The assessment of science skills and processes requires different tools and strategies than the assessment of knowledge. Because skill development is ongoing, students should practise skills throughout the course. Skills are best assessed by observing students in action, by discussing their learning strategies in conferences and interviews, and by gathering data from student reflections and self-assessments.
- **Attitudes:** Attitudes are implicit in what students do and say, and are not always measurable in the way that knowledge outcomes are measurable. Similar to skills, attitudes are best assessed by observing students in action, looking for behavioural indicators as expressions of student attitudes, and engaging students in critical dialogue.

> Rather than emphasizing the recall of specific, detailed and unrelated "facts," [assessment in science] should give greater weight to an assessment of a holistic understanding of the major scientific ideas and a critical understanding of science and science reasoning (Millar and Osborne 25).

Assessment Modes, Strategies, and Tools

Assessment is embedded in the learning process. It is deeply interconnected with curriculum and instruction and must be balanced in order to improve learning and achievement for all students. Cooper suggests teachers consider modes, strategies, and tools when developing assessment tasks:

- **Modes** are the ways in which students demonstrate their learning. They include writing, doing, and speaking, and may be used in combination in an assessment task.
- **Strategies** are the tasks in which the students engage. These include tests and quizzes, journals, inquiry projects, laboratory activities, debates, mind maps, multimedia presentations, and diagrams. The type of strategy selected should match the learning being assessed.
- **Tools** are the instruments used to record the assessment data. Examples of assessment tools are marking schemes, rubrics, checklists, and rating scales. The tool must correspond to the strategy that has been chosen. For example, a rubric is used to assess an open-response essay question or an inquiry project, while a marking scheme is used to assess a multiple choice test.

Assessment Tools and Strategies*	
Observations of Skills and Processes	**Tests, Products, and Performances**
Teacher assessment: • checklists and rating scales • anecdotal records • conferences and interviews • review of work in progress	Teacher assessment: • rubrics and marking scales • conferences • portfolios
Student peer assessment and self-assessment • checklists and rating scales • logs and journals	Student peer assessment and self-assessment • checklists • reflective journals • portfolios

* Source: Manitoba Education, Citizenship and Youth. *Grade 9 Social Studies: Canada in the Contemporary World: A Foundation for Implementation*. Winnipeg, MB: Manitoba Education, Citizenship and Youth, 2007. Adapted from Overview, p. 45.

Characteristics of Effective Assessment**

Effective assessment helps focus effort on implementing strategies to facilitate learning both inside and outside the classroom. Effective assessment is

- congruent with instruction
- ongoing and continuous
- based on authentic tasks
- based on criteria that students know and understand
- a collaborative process involving students
- focused on what students have learned and can do

Effective Assessment Is Congruent with Instruction

Assessment requires teachers and students to be aware continually of the purpose of instruction. How teachers assess depends on what they are assessing—whether it is knowledge, skills, or attitudes. Assessment is intended to inform students of the programming emphases and to help them to focus on important aspects of learning. If teachers assess only the elements that are easiest to measure, students may focus only on those things.

** Source: Manitoba Education and Training. *Senior 3 English Language Arts: A Foundation for Implementation*. Winnipeg, MB: Manitoba Education and Training, 1999. Adapted from Section 2, pp. 10–14.

Effective Assessment Is Ongoing and Continuous

Assessment that is woven into daily instruction offers students frequent opportunities to gain descriptive feedback, to modify their learning approaches and methods, and to observe their progress. Teachers provide assessment for learning by questioning students and offering comments throughout a project or unit of study. They also conduct assessments of learning at the completion of a project or unit of study. Continuous assessment provides ongoing opportunities for teachers to review and revise instruction, content, process emphases, and learning resources, and for students to assess their own knowledge, skills, and learning strategies in order to develop their understanding and to refine their learning strategies.

Effective Assessment Is Based on Authentic Tasks

Assessment tasks in science should be authentic and meaningful—tasks worth doing for their own sake. Through assessment, teachers discover whether students can use knowledge, processes, and resources effectively to achieve worthwhile purposes. Therefore, teachers design tasks that replicate the context in which knowledge will be applied in the world beyond the classroom.

Authentic assessment tasks are tests not only of the information students possess, but also of the way their understanding of a subject has deepened, and of their ability to apply learning. They demonstrate to students the relevance and importance of learning. Performance-based tasks are also a way of consolidating student learning.

Effective Assessment Is Based on Criteria That Students Know and Understand

Assessment criteria must be clearly established and made explicit to students prior to an assignment or test so that students can focus their efforts. Each assessment task should test only those learning outcomes that have been identified to students. This means, for example, that laboratory skills tests need to be devised and marked to gather information about students' laboratory skills, not their ability to express ideas effectively when writing a laboratory report.

Wherever possible, students need to be involved in co-constructing the assessment criteria. Students should also understand clearly what successful accomplishment of each proposed task looks like. Samples of student work from previous years and other exemplars assist students in developing personal learning goals.

Effective Assessment Is a Collaborative Process Involving Students

The ultimate purpose of assessment is to enable students to assess themselves. The gradual increase of student responsibility for assessment is aimed at developing students' autonomy as lifelong learners. Assessment should decrease, rather than foster, students' dependence on teachers' comments for direction in learning and on marks for validation of their accomplishments.

Assessment enhances students' metacognition. It helps them make judgments about their own learning, and provides them with information for goal setting and self-monitoring.

Teachers increase students' responsibility for assessment by

- requiring students to select the products and performances to demonstrate their learning
- involving students in developing assessment criteria whenever possible
- involving students in peer assessment, informally through peer conferences and formally using checklists
- having students use tools for reflection and self-assessment at every opportunity (e.g., self-assessment checklists, journals, identification and selection of goals, self-assessment of portfolio items)
- establishing a protocol for students who wish to challenge a teacher-assigned mark (formal appeals are valuable exercises in persuasive writing, and provide opportunities for students to examine their performance in light of the assessment criteria)

Effective Assessment Is Focused on What Students Have Learned and Can Do

Assessment must be equitable; it must offer opportunities for success to every student. Effective assessment demonstrates the knowledge, skills and strategies, and attitudes of each student and the progress the student is making, rather than simply identifying deficits in learning.

To assess what students have learned and can do, teachers need to use a variety of strategies and approaches, such as the following:

- Use a wide range of instruments to assess the multi-dimensional expressions of each student's learning, avoiding reliance upon rote recall or memorization.
- Provide students with opportunities to learn from feedback and to refine their work, recognizing that not every assignment will be successful, nor will it become part of a summative evaluation.
- Examine several pieces of student work in assessing any particular learning outcome to ensure that data collected are valid bases for making generalizations about student learning.
- Develop complete student profiles by using information from both learning outcome-referenced assessment, which compares a student's performance to predetermined criteria, and self-referenced assessment, which compares a student's performance to her or his prior performance.
- Avoid using assessment for purposes of discipline or classroom control. Ryan, Connell, and Deci found that assessment that is perceived as a tool for controlling student behaviour, meting out rewards and punishments rather than providing feedback on student learning, reduces student motivation.

At times, a common practice was to assign a mark of zero for incomplete student work. However, averaging a zero into the student's mark means the mark no longer communicates accurate information about the student's achievement of science learning outcomes. Unfinished assignments signal personal or motivational problems that need to be addressed in appropriate and alternative ways.

- Allow students, when appropriate and possible, to choose how they will demonstrate their competence.
- Use assessment tools appropriate for assessing individual and unique products, processes, and performances.

For more information regarding assessment, consult the following documents:

- *Communicating Student Learning: Guidelines for Schools* (Manitoba Education, Citizenship and Youth)
- *Provincial Assessment Policy, Kindergarten to Grade 12: Academic Responsibility, Honesty, and Promotion/Retention* (Manitoba Education)
- *Rethinking Classroom Assessment with Purpose in Mind: Assessment for Learning, Assessment as Learning, Assessment of Learning* (Manitoba Education, Citizenship and Youth)

Notes

SECTION 3: DOCUMENT ORGANIZATION

DOCUMENT ORGANIZATION

Document Organization and Format

The suggestions for instruction and assessment contained within *Grade 12 Biology: A Foundation for Implementation* provide teachers with strategies for assisting students in achieving the general and specific learning outcomes identified for this curriculum. The instructional and assessment suggestions offer teachers a range of strategies from which to select appropriate directions with students. Although they are not prescriptive, the strategies presented can be considered starting points from which teachers can include their own initiatives, style, and effective techniques to foster learning.

The topic-related appendices (found at the end of each unit) and the general appendices (found at the end of this document) provide additional information on student learning activities, teacher support materials related to instruction and assessment, and a variety of assessment rubrics. These complementary resources are closely linked to the specific learning outcomes and to the skills and attitudes outcomes, and are designed to support, facilitate, and enhance student learning.

At-a-glance listings of the general learning outcomes, skills and attitudes outcomes, and specific learning outcomes for Grade 12 Biology are provided in Appendix 11.

Guide to Reading the Learning Outcomes and the Document Format

The specific learning outcomes identified for Grade 12 Biology are organized according to five units:

- Unit 1: Understanding Biological Inheritance
- Unit 2: Mechanisms of Inheritance
- Unit 3: Evolutionary Theory and Biodiversity
- Unit 4: Organizing Biodiversity
- Unit 5: Conservation of Biodiversity

The suggested strategies for implementing the curriculum outcomes within each biology unit include the following components:

- **Specific Learning Outcomes (SLOs):** The SLOs, identified at the top of each page within the units, outline the intended learning to be achieved by the student by the end of the course. They include the SLOs related to the particular biology topic, in addition to the learning outcomes related to Cluster 0: Skills and Attitudes, selected to correspond to the Suggestions for Instruction.

- **General Learning Outcome (GLO) Connections:** The GLOs, found in Appendix 11, provide links across the entire scope of the Kindergarten to Grade 12 continuum of learning in science. These GLOs provide connections to the Five Foundations for Scientific Literacy that guide all Manitoba science curricula in all science discipline areas.

- **Suggestions for Instruction:** The instructional strategies relate directly to the achievement of the identified SLOs. In each unit, SLOs may be grouped into related topics.
- **Entry-Level Knowledge:** Students will have prior knowledge in relation to some learning outcomes. Identification of students' entry-level knowledge, where included, links teachers to key areas of the science curriculum from previous years, providing information about where students should be in relation to the present learning outcomes.
- **Background Information:** These notes provide teachers with content background (often beyond what the students are required to know) related to the identified learning outcomes.
- **Teacher Notes:** These notes, incorporated throughout the document, provide teachers with planning hints, cautions, and information on the depth of treatment of certain issues related to the identified learning outcomes.
- **Activate:** By activating students' prior knowledge of a topic, teachers can recognize gaps and misconceptions in students' knowledge and adjust instruction appropriately; stimulate students' curiosity and initiate the inquiry process; and help students relate new information, skills, and strategies to what they already know and can do. Suggested activating strategies are provided for all groupings of SLOs.
- **Acquire/Apply:** These instructional strategies are designed to assist students in processing, integrating, and consolidating their learning. The examples of teacher-facilitated acquiring and applying strategies presented in this document are designed to be student-centred, engaging the learner directly in some contextual way. The skills linked to the suggested acquiring and applying strategies are provided as well.

- **Culminating Tasks:** These tasks (identified by the CT graphic shown on the left) are designed to integrate several learning outcomes and skills and attitudes outcomes of a unit into one major assignment. A culminating task is suggested in each unit of the course.

- **Suggestions for Assessment:** These suggestions offer strategies for assessing students' achievement of the SLOs. They are identified by the graphic shown on the left.
- **Resource Links:** The links to websites suggested within the units are intended to provide additional resources to support student learning. They include the websites listed on the following pages.

> **Note:** These websites were accessed on May 5, 2011 (unless specified otherwise). Any websites referenced in this document are subject to change. If the sites become inactive, please use a search engine to locate the online resources.

Resource Links

Agriculture in the Classroom. "DNA Extraction Lab Protocol." Rev. 11 Apr. 2011. Multimedia Educational Resource for Learning and Online Teaching (MERLOT). <www.merlot.org/merlot/viewMaterial.htm?id=423595>.

Alberta Riparian Habitat Management Society—Cows and Fish. *Biodiversity and Riparian Areas: Life in the Green Zone.* Lethbridge, AB: Cows and Fish, Feb. 2002. Available on the Cows and Fish website at <www.cowsandfish.org/pdfs/biodiversity.pdf>.

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Canadian Association of Genetic Counsellors. Home Page. <www.cagc-accg.ca/>.

Canadian Fossil Discovery Centre. Home Page. <www.discoverfossils.com/>.

Canadian Hemophilia Society. Home Page. <www.hemophilia.ca/>.

Canadian Museum of Nature. *The GEEE! in Genome.* <www.nature.ca/genome/index_e.cfm>.

The Canadian Society for Mucopolysaccharide and Related Diseases Inc. Home Page. <www.mpssociety.ca/>.

Canadian Water Resources Association (CWRA). *Project WET.* <www.cwra.org/branches/ProjectWet/>.

Canadian Wildlife Federation (CWF). Home Page. <www.cwf-fcf.org/>.

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Canadian Wildlife Service and Canadian Wildlife Federation. *Hinterland Who’s Who.* <www.hww.ca/>.

Canon Envirothon. Home Page. <www.envirothon.org/>.

Carnegie Institution for Science. “Sickle Cell Anemia.” <http://carnegiescience.edu/first_light_case/horn/lessons/sickle.html>.

Cold Spring Harbor Laboratory’s DNA Learning Center. *DNA from the Beginning*. <www.dnaftb.org/>.

———. *DNA Interactive.* <www.dnai.org/>.

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———. *Lab Center at DNALC.* <http://labcenter.dnalc.org/dnalc.html>.

———. *Online Education Websites*. <www.dnalc.org/websites/>.

———. *Your Genes, Your Health*. <www.ygyh.org/>.

The Complete Work of Charles Darwin Online. Home Page. <www.darwin-online.org.uk/>.

Council for Biotechnology Information. *Canada: English.* <www.whybiotech.ca/>.

CropLife Canada. *Biotechnology*. <www.croplife.ca/web/english/biotechnology/>.

Crop Protection Institute of Canada. *Plant Biotechnology: A Secondary School Teacher’s Resource Manual.* CropLife Canada. <www.croplife.ca/english/pdf/CPI_Biotech_Manual.pdf>.

Cystic Fibrosis Canada. Home Page. <www.cysticfibrosis.ca/>.

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Environment Canada. “Education and Awareness.” Canadian Biodiversity Information Network. <www.cbin.ec.gc.ca/education/>.

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Sample Two-Page Layout

The following clarification on reading the document format is based on a sample two-page layout from *Grade 12 Biology: A Foundation for Implementation*.

Indicates the biology topic.

Specific learning outcome (SLO) statements define what students are expected to achieve by the end of Grade 12 Biology.

The first alpha-numeric code indicates course (Grade 12 Biology); second digit indicates topic number; and third digit(s) indicate(s) specific learning outcome number.

Suggestions for student learning experiences relate directly to the attainment of the specific learning outcome(s).

Include: Indicates a mandatory component of the specific learning outcome, or a defined set of limitations.

Examples: Provide ideas of what could be included (non-mandatory). (This specific learning outcome does not contain this component.)

Teacher notes provide teachers with background information, definitions, planning hints, special-interest material, and information on depth of treatment of certain issues. Safety information and cautions are included.

GRADE 12 BIOLOGY • *Unit 1: Understanding Biological Inheritance*

AUTOSOMAL INHERITANCE

SPECIFIC LEARNING OUTCOME

B12-1-04: Use Punnett squares to solve a variety of autosomal inheritance problems, and justify the results using appropriate terminology. (GLOs: D1, E1)

Include: monohybrid cross, dihybrid cross, testcross, P generation, F_1 generation, F_2 generation, phenotypic ratio, genotypic ratio, dominant alleles, recessive alleles, purebred, hybrid, and carrier

SLO: B12-1-04

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

Students observed, collected, and analyzed data of single-trait inheritance in Grade 9 Science. At that time, students were introduced to Punnett squares and solved single-trait inheritance problems.

TEACHER NOTE

Students often ask where the F in F_1 and F_2 come from, and why they are not called the C (child) and G (grandchild) generations. Explain that the F comes from the Latin word *filial*, which refers to offspring or children.

ACTIVATE

Turn to Your Neighbour

Pose the following genetics problem to students:

- Short hair is dominant over long hair in dogs. Two dogs … short hair produce a litter of eight pups. Predict the appe… and explain how you arrived at your prediction.

Students turn to their neighbours to discuss their prediction…

ACQUIRE/APPLY

Problem-Solving Approaches—Class Discussion (S1, G…

Discuss with students their approaches/steps to solving the problem posed in Turn to Your Neighbour. As the discussion progresses, review with students the conventions used in solving genetics problems. For example, the dominant gene is written first in the heterozygous condition (i.e., Ss, not sS).

Suggestion for Assessment

Use the Thumbs strategy—thumbs up (I get it), thumbs down (I don't get it), thumbs sideways (I'm not sure I get it)—to check students' understanding. This strategy can be used as a quick formative assessment to adjust the pace of instruction.

12 – Understanding Biological Inheritance

Skills and attitudes learning outcomes define expectations across all topics in Grade 12 Biology.

GRADE 12 BIOLOGY • *Unit 1: Understanding Biological Inheritance*

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort and predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Building Vocabulary (U1)

Introduce new vocabulary to students as required. The use of a variety of strategies (e.g., Three-Point Approach, Sort and Predict, Word Clusters) can aid students in developing both conceptual and contextual knowledge of the vocabulary of genetics. For more information on building a scientific vocabulary and for think-sheet frames, refer to *SYSTH* (Chapter 10).

Resource Link

- The National Science Digital Library. Home Page. <http://nsdl.org/>.
  The collections of genetics resources for teachers on this website include lesson plans, videos, interactives, and articles.

Suggestion for Assessment

Review students' think-sheet frames to ensure accuracy. As this learning activity is intended as a formative assessment to check students' understanding, no mark is required.

Understanding Biological Inheritance – 13

Code refers to skills and attitudes learning outcome(s).

Resource links indicate the titles, authors, and page references (or URLs) where SLO-related content is treated within the various learning resources.

Suggested strategies relate directly to assessing student achievement of the specific learning outcome(s). Suggestions for assessment are identified by the graphic shown on the left.

NOTES

Part 1: Genetics

Unit 1: Understanding Biological Inheritance

Unit 1: Understanding Biological Inheritance

Specific Learning Outcomes

B12-1-01: Outline Gregor Mendel's principles of inheritance, stating their importance to the understanding of heredity. (GLOs: A1, A2, B1, D1)

Include: principles of segregation, dominance, and independent assortment

B12-1-02: Explain what is meant by the terms *heterozygous* and *homozygous*. (GLO: D1)

B12-1-03: Distinguish between *genotype* and *phenotype*, and use these terms appropriately when discussing the outcomes of genetic crosses. (GLO: D1)

B12-1-04: Use Punnett squares to solve a variety of autosomal inheritance problems, and justify the results using appropriate terminology. (GLOs: D1, E1)

Include: monohybrid cross, dihybrid cross, testcross, P generation, F_1 generation, F_2 generation, phenotypic ratio, genotypic ratio, dominant alleles, recessive alleles, purebred, hybrid, and carrier

B12-1-05: Describe examples of and solve problems involving the inheritance of phenotypic traits that do not follow a dominant-recessive pattern. (GLO: D1)

Examples: co-dominance, incomplete dominance, multiple alleles, lethal genes . . .

B12-1-06: Explain the basis for sex determination in humans. (GLO: D1)

Include: XX and XY chromosomes

B12-1-07: Describe examples of and solve problems involving sex-linked genes. (GLO: D1)

Examples: red-green colour-blindness, hemophilia, Duchenne muscular dystrophy . . .

B12-1-08: Use pedigree charts to illustrate the inheritance of genetically determined traits in a family tree and to determine the probability of certain offspring having particular traits. (GLOs: C8, D1)

Include: symbols and notations used

B12-1-09: Discuss ethical issues that may arise as a result of genetic testing for inherited conditions or disorders. (GLOs: A3, B1, B2, C4)

B12-1-10: Discuss the role of meiosis and sexual reproduction in producing genetic variability in offspring. (GLOs: D1, E3)

Include: crossing over and randomness

B12-1-11: Explain how chromosome mutations may arise during meiosis. (GLOs: D1, E3)

Include: nondisjunction

B12-1-12: Identify monosomy and trisomy chromosome mutations from karyotypes. (GLO: D1)

Examples: Down syndrome, Turner syndrome, Klinefelter syndrome

PRINCIPLES OF INHERITANCE

SPECIFIC LEARNING OUTCOMES

B12-1-01: Outline Gregor Mendel's principles of inheritance, stating their importance to the understanding of heredity. (GLOs: A1, A2, B1, D1)

Include: principles of segregation, dominance, and independent assortment

B12-1-02: Explain what is meant by the terms *heterozygous* and *homozygous*. (GLO: D1)

B12-1-03: Distinguish between *genotype* and *phenotype*, and use these terms appropriately when discussing the outcomes of genetic crosses. (GLO: D1)

SLO: B12-1-01
SLO: B12-1-02
SLO: B12-1-03

SUGGESTIONS FOR INSTRUCTION

TEACHER BACKGROUND

The instructional strategies suggested in this document follow the constructivist model of learning and are organized into two groups: activate and acquire/apply.

By activating students' prior knowledge of a topic, teachers can

- help students relate new information, skills, and strategies to what they already know and can do
- recognize misconceptions and gaps in student knowledge
- stimulate curiosity and initiate the inquiry process

Acquiring and applying strategies are designed to assist students in processing, integrating, and consolidating their learning.

ENTRY-LEVEL KNOWLEDGE

Students were exposed to basic Mendelian genetics in Grade 9 Science. Dominant and recessive genes were discussed, and the terms *genotype* and *phenotype* were introduced.

TEACHER NOTE

Students generally find the study of genetics interesting. Once they learn the specialized vocabulary and conventions (e.g., Punnett squares), the concepts can be easy to grasp.

Ensure students understand that Gregor Mendel had no preconceptions about chromosomes, genes, or deoxyribonucleic acid (DNA). He based his principles solely on the numbers of offspring he observed. The scientific process Mendel used could be a theme during instruction for learning outcome B12-1-01.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

ACTIVATE

Traffic Lights

Prepare a Traffic Lights handout containing 10 to 20 terms related to genetics. Some words may be familiar to students from Grade 9 Science (e.g., dominant, recessive, genotype, phenotype, Punnett square, heredity, homozygous, heterozygous), while other terms may not be familiar to students (e.g., independent assortment, Gregor Mendel, purebred, hybrid, allele, carrier). Provide students with red, yellow, and green highlighters or sheets of peel-off dots. Students use green to point out terms/concepts they understand, yellow to indicate those they are somewhat familiar with, and red to show those they are unfamiliar with or don't understand (Keeley).

Suggestion for Assessment

Scan the completed Traffic Lights handouts to assess students' understanding of vocabulary and concepts. The information gathered from this formative assessment can be used to plan for instruction. Should the majority of students in the class indicate little or no understanding of or familiarity with genetics terms or concepts, an adjustment in the instructional plan is required to help students develop their conceptual understanding.

PRINCIPLES OF INHERITANCE

SPECIFIC LEARNING OUTCOMES

B12-1-01: Outline Gregor Mendel's principles of inheritance, stating their importance to the understanding of heredity. (GLOs: A1, A2, B1, D1)

Include: principles of segregation, dominance, and independent assortment

B12-1-02: Explain what is meant by the terms *heterozygous* and *homozygous*. (GLO: D1)

B12-1-03: Distinguish between *genotype* and *phenotype*, and use these terms appropriately when discussing the outcomes of genetic crosses. (GLO: D1)

Rotational Cooperative Graffiti

For this brainstorming activity, organize students into small groups. Give each group a unique topic, as well as poster paper and a marker. (Marker colours are different for each group.) The groups brainstorm as many ideas as they have about the given topic—anything that comes to mind. After the groups have brainstormed ideas for a predetermined period of time, they pass their poster papers to the next group. Once again, the groups record their responses to the topic on the posters. This process continues until each group gets its original poster back. Group members work together to summarize what has been written on their poster. They then share the summary with the class.

Topics may include the following:

- dominant/recessive
- genotype/phenotype
- homozygous/heterozygous
- meiosis/mitosis
- pedigree
- Punnett square

For more information on this strategy, refer to *Senior Years Science Teachers' Handbook: A Teaching Resource* (Manitoba Education and Training, p. 3.15)—hereafter referred to as *SYSTH*.

ACQUIRE/APPLY

Building Vocabulary (U1)

Introduce new vocabulary to students as required. Students benefit from receiving assistance with vocabulary before they start to read science texts. The use of a variety of strategies (e.g., Word Cycle, Three-Point Approach) can aid students in developing both conceptual and contextual knowledge of the genetics-related vocabulary. For more information on building a scientific vocabulary and think-sheet frames, refer to *SYSTH* (Chapter 10).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

Suggestion for Assessment

Completed think-sheet frames can be peer assessed or handed in for teacher feedback. As this learning activity is intended as a formative assessment to check student understanding, a mark is not required. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

The Story of Gregor Mendel—Article Analysis (U1, N2)

The story of Gregor Mendel is a fascinating one. For a brief summary of his life and work, see Appendix 1.1: The Story of Gregor Mendel (BLM). Ask students to read the article and complete a Fact-Based Article Analysis frame (see *SYSTH* pp. 11.30–11.31, 11.41).

Encourage students to use effective reading strategies to acquire new knowledge from text. This includes activating prior knowledge before the reading, taking some form of notes during the reading, and having the opportunity to discuss/reflect on what they read. For more information about strategies for reading scientific information, refer to *SYSTH* (Chapter 12).

Suggestion for Assessment

Scan the completed Fact-Based Article Analysis frames to assess students' understanding. The information gathered can be used to plan further instruction.

PRINCIPLES OF INHERITANCE

SPECIFIC LEARNING OUTCOMES

B12-1-01: Outline Gregor Mendel's principles of inheritance, stating their importance to the understanding of heredity. (GLOs: A1, A2, B1, D1)

Include: principles of segregation, dominance, and independent assortment

B12-1-02: Explain what is meant by the terms *heterozygous* and *homozygous*. (GLO: D1)

B12-1-03: Distinguish between *genotype* and *phenotype*, and use these terms appropriately when discussing the outcomes of genetic crosses. (GLO: D1)

Mendel's Experiments (U1, N1)

Use diagrams and charts to illustrate Mendel's experiments, observations, and conclusions. The use of visuals will aid students in developing their understanding of the concept of inheritance.

The 10 + 2 Note-Taking strategy can assist students in developing their conceptual understanding. In using this strategy, the teacher presents information for 10 minutes, and then each student summarizes or discusses the material with a partner for two minutes.

Resource Links

- Cold Spring Harbor Laboratory's DNA Learning Center. Home Page. <www.dnalc.org/>.
- ———. *DNA from the Beginning.* <www.dnaftb.org/>.
  This website contains an animated primer on the basics of DNA, genes, and heredity.
- ———. *Lab Center at DNALC.* <http://labcenter.dnalc.org/dnalc.html>.
- ———. *Online Education Websites.* <www.dnalc.org/websites/>.
- Genetic Science Learning Center. *Learn.Genetics.* <http://learn.genetics.utah.edu>.
  The *Heredity and Traits* section of this website provides tutorials and interactive animations.
- McBrien, Amanda. "Lab: Mendelian Inheritance." *Dolan DNA Learning Center.* <http://labcenter.dnalc.org/mendeliangenetics/mendeliangenetics_d.html>.
  A cob of corn (*Zea mays*) with purple and yellow kernels in a 3:1 phenotype ratio is required in one of the learning activities.
- The National Science Digital Library (NSDL). Home Page. <http://nsdl.org/>.
  The collections of genetics resources for teachers on this website include lesson plans, videos, interactives, and articles.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

- Nature Education. *Scitable: A Collaborative Learning Space for Science.* <www.nature.com/scitable>.

  The science library on this website contains articles, concept overviews, and animations focusing on genetics and evolution. Teachers can build online classrooms to share and discuss articles with students.

Suggestion for Assessment

During the last five minutes of the class, have students reflect on their learning by completing an Exit Slip, responding to questions such as the following:

- What do you know now that you didn't know before class today?
- What did you already know?
- What questions do you still have?

Review student responses, looking for areas of confusion, and address the questions during the next class (formative assessment). For information on Exit Slips, see *SYSTH* (p. 13.9).

Family Traits (U2)

Show the class a picture of a family (parents and their children). Pose the following question to students and ask them to respond in their notebooks.

- The children in a family resemble each other and their parents, but they are not identical to each other (except in the case of identical twins) or to their parents. Can you explain why this is so?

PRINCIPLES OF INHERITANCE

SPECIFIC LEARNING OUTCOMES

B12-1-01: Outline Gregor Mendel's principles of inheritance, stating their importance to the understanding of heredity. (GLOs: A1, A2, B1, D1)

Include: principles of segregation, dominance, and independent assortment

B12-1-02: Explain what is meant by the terms *heterozygous* and *homozygous*. (GLO: D1)

B12-1-03: Distinguish between *genotype* and *phenotype*, and use these terms appropriately when discussing the outcomes of genetic crosses. (GLO: D1)

Suggestion for Assessment

This question can be used as a formative assessment to observe the level of student understanding of this concept and to help plan future lessons.

Mendel's Results—Data Analysis (S4, S5, N1)

Provide students with samples of Mendel's raw data and ask them to determine which traits are dominant and which traits are recessive. Students should be able to explain the reasons for their choices.

Parental Traits	F_1 Progeny	F_2 Progeny
wrinkled x round (seeds)	all round	5472 round, 1850 wrinkled
yellow x green (seeds)	all yellow	6022 yellow, 2001 green
tall x short (plant height)	all tall	787 tall, 277 short

Resource Link

- Mendel, Gregor. "Experiments in Plant Hybridization." 1865. Trans. William Bateson. *MendelWeb*. <www.mendelweb.org/Mendel.html>.

Suggestion for Assessment

Make an accounting of the ratios of some simple Mendelian characteristics among the students in your class (e.g., tongue curling, mid-digit hair, attached/free earlobes). Ask students to determine (if possible) their genotypes for these characteristics by comparing how they express a characteristic with how each of their parents expresses that characteristic.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

Mendel's Publication—Creative Writing Assignment (U2, I4)

RAFTs (Role–Audience–Format–Topic–Strong Verbs) are creative writing assignments in which students are encouraged to adopt new perspectives on a science concept or issue (for more information, refer to *SYSTH*, pp. 13.22–13.25). In this learning activity, students assume the persona of Gregor Mendel and write an article for publication in a scientific journal detailing his findings. Refer to Appendix 1.2: Mendel's Publication—Creative Writing Assignment (BLM) for assignment details.

Suggestions for Assessment

Create an assessment rubric for the assignment by developing the assessment criteria and performance levels in collaboration with students. Assessment criteria could include biology content, information sources, organization, and so on. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. Alternatively, provide students with exemplars of strong and weak assignments, and have them work in groups to identify possible assessment criteria and levels of performance. The exemplars can be teacher-generated or anonymous samples of student work done in previous years.

AUTOSOMAL INHERITANCE

SPECIFIC LEARNING OUTCOME

B12-1-04: Use Punnett squares to solve a variety of autosomal inheritance problems, and justify the results using appropriate terminology. (GLOs: D1, E1)

Include: monohybrid cross, dihybrid cross, testcross, P generation, F_1 generation, F_2 generation, phenotypic ratio, genotypic ratio, dominant alleles, recessive alleles, purebred, hybrid, and carrier

SLO: B12-1-04

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

Students observed, collected, and analyzed data of single-trait inheritance in Grade 9 Science. At that time, students were introduced to Punnett squares and solved single-trait inheritance problems.

TEACHER NOTE

Students often ask where the F in F_1 and F_2 come from, and why they are not called the C (child) and G (grandchild) generations. Explain that the F comes from the Latin word *filial*, which refers to offspring or children.

ACTIVATE

Turn to Your Neighbour

Pose the following genetics problem to students:

- Short hair is dominant over long hair in dogs. Two dogs heterozygous for short hair produce a litter of eight pups. Predict the appearance of the pups and explain how you arrived at your prediction.

Students turn to their neighbours to discuss their predictions and explanations.

ACQUIRE/APPLY

Problem-Solving Approaches—Class Discussion (S1, G2)

Discuss with students their approaches/steps to solving the problem posed in Turn to Your Neighbour. As the discussion progresses, review with students the conventions used in solving genetics problems. For example, the dominant gene is written first in the heterozygous condition (i.e., Ss, not sS).

Suggestion for Assessment

Use the Thumbs strategy—thumbs up (I get it), thumbs down (I don't get it), thumbs sideways (I'm not sure I get it)—to check students' understanding. This strategy can be used as a quick formative assessment to adjust the pace of instruction.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Building Vocabulary (U1)

Introduce new vocabulary to students as required. The use of a variety of strategies (e.g., Three-Point Approach, Sort and Predict, Word Clusters) can aid students in developing both conceptual and contextual knowledge of the vocabulary of genetics. For more information on building a scientific vocabulary and for think-sheet frames, refer to *SYSTH* (Chapter 10).

Resource Link

- The National Science Digital Library. Home Page. <http://nsdl.org/>.
  The collections of genetics resources for teachers on this website include lesson plans, videos, interactives, and articles.

Suggestion for Assessment

Review students' think-sheet frames to ensure accuracy. As this learning activity is intended as a formative assessment to check students' understanding, no mark is required.

AUTOSOMAL INHERITANCE

SPECIFIC LEARNING OUTCOME

B12-1-04: Use Punnett squares to solve a variety of autosomal inheritance problems, and justify the results using appropriate terminology. (GLOs: D1, E1)

Include: monohybrid cross, dihybrid cross, testcross, P generation, F_1 generation, F_2 generation, phenotypic ratio, genotypic ratio, dominant alleles, recessive alleles, purebred, hybrid, and carrier

Probability Investigation (P1, S2, S3, S4)

Probability investigations are relatively simple to perform, involving marking and tossing coins to illustrate how probability can be used to predict the outcomes of genetic crosses. Refer to Appendix 1.3: Student Lab Skills (Teacher Background) for information on assessing and evaluating student lab skills.

Suggestion for Assessment

Assessment of this investigation can be summative (written responses to the questions posed) or formative. The RERUN strategy (Keeley 172–73) can be used for formative assessment of student learning in place of a formal summative lab report.

After students have completed the investigation and answered questions about it, ask them to reflect on their lab experience (individually or in groups) by writing a sentence or two for each letter of the acronym, **RERUN**: **R**ecall (what you did), **E**xplain (why you did it), **R**esults (what you found out), **U**ncertainties (what remains unclear), and **N**ew (what you learned).

Genetics Problems—Each One Teach One (U2, G2)

Provide pairs of students with a variety of genetics problems. Students work collaboratively to solve the problems and explain their metacognitive processes to each other (they explain how they were able to determine the answers to the problems). See Appendix 1.7A: Genetics Problems 1 and Appendix 1.7B: Genetics Problems 1 (Answer Key). The sample problems and answers provide examples of typical problems and expected solutions.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Suggestion for Assessment

Completed work can be handed in for teacher feedback. Provide feedback that is specific and descriptive, describing the performance rather than making a judgment or giving an opinion. This will help students repeat success and know what they need to improve. General comments (e.g., “Try harder next time” or “Good work”) are less effective than specific and descriptive comments (e.g., “You have correctly determined the genotypes of the parents and possible offspring; however, you did not include the probability that the next child will be a carrier of the disease”).

AUTOSOMAL INHERITANCE

SPECIFIC LEARNING OUTCOME

B12-1-04: Use Punnett squares to solve a variety of autosomal inheritance problems, and justify the results using appropriate terminology. (GLOs: D1, E1)

Include: monohybrid cross, dihybrid cross, testcross, P generation, F_1 generation, F_2 generation, phenotypic ratio, genotypic ratio, dominant alleles, recessive alleles, purebred, hybrid, and carrier

Determining the Inheritance Pattern of a Trait—Investigation/Culminating Task (S1, S2, S3, S4, S5, I4, G1, G3)

Students investigate to determine the inheritance pattern of a trait in an organism, documenting and reflecting on the inquiry process. An investigation of this sort can be used as a culminating task for the unit, bringing together a number of knowledge and skills outcomes. Students can work on this investigation throughout the unit. Refer to Appendix 1.5: Scientific Inquiry (BLM) and Appendix 1.6A: Feedback Form for Designing an Experiment (Plan) (BLM).

Resource Links

- Lauffer, D., and P. Williams. Wisconsin Fast Plants. Home Page. <www.fastplants.org/>.

  The fruit fly (*Drosophila melanogaster*) and Wisconsin Fast Plants (*Brassica rapa*) are easy to work with and have short breeding cycles. The results of breeding several generations can easily be observed to determine the inheritance patterns of a variety of traits. Purebred fruit flies and Wisconsin Fast Plants can be obtained from biological supply companies.

- University of Massachusetts Boston. *Virtual Genetics Lab*. <http://intro.bio.umb.edu/vgl/>.

  In this simulation of the transmission of traits in a hypothetical organism, students determine the mechanism of inheritance of a particular trait based on the logic of genetic analysis.

Suggestions for Assessment

The results of the investigation can be expressed in a written report or a multimedia presentation. Laboratory and group work skills can be assessed using checklists. Refer to Appendix 1.3: Student Lab Skills (Teacher Background), Appendix 1.4A: Lab Skills Checklist—General Skills (BLM), Appendix 1.4B: Lab Skills Checklist—Thinking Skills (BLM), and Appendix 1.6B: Rating Scale for Experimental Design and Report (BLM). See *SYSTH* (pp. 11.26–11.29 and 14.11–14.12) for different ways of writing a lab report.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Create an assessment rubric for the report/presentation by developing the assessment criteria and performance levels in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. Alternatively, provide students with exemplars of strong and weak lab reports, and have them work in groups to identify possible assessment criteria and levels of performance. The exemplars can be anonymous samples of student work done in previous years.

ATYPICAL INHERITANCE

SPECIFIC LEARNING OUTCOME

B12-1-05: Describe examples of and solve problems involving the inheritance of phenotypic traits that do not follow a dominant-recessive pattern. (GLO: D1)

Examples: co-dominance, incomplete dominance, multiple alleles, lethal genes . . .

SLO: B12-1-05

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Specialized conventions that indicate co-dominant, incomplete dominant, and multiple allele genotypes can be confusing to students. Introduce the specialized conventions that indicate co-dominant, incomplete dominant, and multiple allele genotypes. With the use of examples, show how the expression of these traits varies from the typical Mendelian ratios.

BACKGROUND INFORMATION

When two alleles of a gene are clearly expressed in the phenotype, the alleles are said to be co-dominant. For example, the roan (pinkish) colour in cattle is the result of the coat being a mix of both red and white hair. The AB blood type in humans is the result of an individual carrying both the I^A and I^B alleles.

When two alleles of a gene appear to be blended in the phenotype, the alleles are said to show incomplete dominance. For example, when red-flowered snapdragons are crossed with white-flowered snapdragons, all the offspring (F_1 generation) have pink flowers. If the pink-flowered snapdragons are allowed to self-pollinate, the F_2 generation ratio is 1 red: 2 pink: 1 white.

Some genes may have three or more alleles; however, each individual can have a maximum of two alleles per gene. Human ABO blood types are examples of multiple alleles. Four possible phenotypes (A, B, AB, O) are produced from three different alleles (I^A—dominant, I^B—dominant, i—recessive).

Some genes are lethal when present in the homozygous condition. In chickens, when a developing embryo contains two copies of a recessive gene known as creeper, the embryo dies inside the eggshell. Chicks heterozygous for the condition survive.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

ACTIVATE

Think-Pair-Share

Provide students with the following information:

> When Gregor Mendel crossed a purple-flowered pea plant with a white-flowered pea plant, the flowers in the next generation were all purple. However, the cross between a red-flowered snapdragon and a white-flowered snapdragon produces pink-flowered snapdragons.

Pose the following questions to students:

- What is the dominant flower colour in pea plants?
- How does the snapdragon cross differ from the pea plant cross?
- Based on your knowledge of alleles and phenotypes, can you provide an explanation for the results of the snapdragon cross?

Give students time to think about the questions and formulate responses individually. Students then pair up with a partner to discuss their ideas.

ACQUIRE/APPLY

Genetics Problems—Each One Teach One (U2, G2)

Provide pairs of students with a variety of genetics problems. Students work collaboratively to solve the problems and explain their metacognitive processes to their partners. See Appendix 1.8A: Genetics Problems 2 (BLM) and Appendix 1.8B: Genetics Problems 2 (Answer Key). The sample problems and answers provide examples of typical problems and expected solutions.

ATYPICAL INHERITANCE

SPECIFIC LEARNING OUTCOME

B12-1-05: Describe examples of and solve problems involving the inheritance of phenotypic traits that do not follow a dominant-recessive pattern. (GLO: D1)

Examples: co-dominance, incomplete dominance, multiple alleles, lethal genes . . .

Suggestion for Assessment

Completed work can be handed in for teacher feedback. Provide feedback that is specific and descriptive, describing the performance rather than making a judgment or giving an opinion. This will help students repeat success and know what they need to improve. General comments (e.g., "Try harder next time" or "Good work") are less effective than specific and descriptive comments (e.g., "You have correctly determined the genotypes of the parents and possible offspring; however, you did not include the probability that the next child will have the AB blood type").

Atypical Inheritance Patterns—Demonstrating Understanding (U1)

At the end of the lesson, pose the following questions to students:

- How do co-dominance and incomplete dominance patterns differ from one another? Explain.
- How do multiple alleles and polygenic traits differ from one another? Explain.

Give students five minutes to respond in their notebooks.

Suggestion for Assessment

This learning activity provides a quick formative assessment of what students learned in a particular lesson. Students' responses should include the following:

- The co-dominance pattern shows the expression of two traits, while the incomplete dominance pattern shows a blending of two traits.
- Multiple allele inheritance shows many forms of a trait, but each individual has only two alleles for the trait. Polygenic inheritance shows a continuum of the forms of the trait, with each individual having many genes involved in the expression of the trait.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

Atypical Inheritance Patterns—Research and Presentation (U2, S1, I1, I3, I4)

Students research and prepare reports explaining the inheritance of phenotypic traits that do not follow a dominant-recessive pattern. Examples include

- human AB blood type, sickle-cell anemia in humans (co-dominance)
- familial hypercholesterolemia in humans, straight/wavy/curly hair in Caucasians, flower colour in four o'clocks, feather colour in Andalusian chickens (incomplete dominance)
- coat colour in rabbits, kernel colour in corn, chicken feather colour (multiple alleles)
- achondroplasia in humans, flower colour in golden snapdragons, coat colour in yellow mice (lethal genes)

Resource Links

- Manitoba Education. *Information and Communication Technology (ICT): Kindergarten to Grade 12*. <www.edu.gov.mb.ca/k12/tech/index.html>.

  Refer to this website for ideas about integrating information and communication technologies across the curriculum.

- ———. "Professional Learning for Teachers." *Literacy with ICT across the Curriculum: A Developmental Continuum.* <www.edu.gov.mb.ca/k12/tech/lict/let_me_try/le_teachers.html>.

  Refer to this website for additional information on topics such as plagiarism, evaluating web content, copyright, and making a bibliography.

ATYPICAL INHERITANCE

SPECIFIC LEARNING OUTCOME

B12-1-05: Describe examples of and solve problems involving the inheritance of phenotypic traits that do not follow a dominant-recessive pattern. (GLO: D1)

Examples: co-dominance, incomplete dominance, multiple alleles, lethal genes . . .

Suggestions for Assessment

Students present their research on the inheritance of phenotypic traits that do not follow a dominant-recessive pattern. Research findings can be presented as

- written reports
- visual displays (e.g., poster, brochure, bulletin board, comic strip)
- oral presentations
- multimedia presentations (e.g., podcast, wiki, PowerPoint, video)

Presentation components may vary, depending on the type of presentation selected. Refer to Appendix 5.8: Checklist for Creating Visuals (BLM) for use with visuals (e.g., posters, collages, graphic organizers) and Appendix 5.9: Oral Presentation—Observation Checklist (BLM).

Develop assessment criteria for the presentation in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on this collaborative process. The criteria should include both content and presentation components. The content criteria should include use of key terms and understandings from the unit.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

NOTES

Sex-Linked Inheritance

SPECIFIC LEARNING OUTCOMES

B12-1-06: Explain the basis for sex determination in humans. (GLO: D1)

Include: XX and XY chromosomes

B12-1-07: Describe examples of and solve problems involving sex-linked genes. (GLO: D1)

Examples: red-green colour-blindness, hemophilia, Duchenne muscular dystrophy . . .

SLO: B12-1-06
SLO: B12-1-07

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 9 Science, students were introduced to the role played by human X and Y chromosomes in sex determination. The inheritance of sex-linked traits was also discussed.

TEACHER NOTE

The specialized conventions that indicate sex chromosomes and sex-linked genes can be confusing to students. Introduce the specialized conventions that indicate sex chromosomes and sex-linked traits. With the use of examples, show how the expression of sex-linked traits varies from the typical Mendelian ratios.

Be sensitive to the fact that students in your class may have a sex-linked condition (e.g., approximately 1 in 10 males and 1 in 100 females have red-green colour-blindness), or it may run in their families. Hemophilia strikes an estimated 1 in 7500 boys; Duchenne muscular dystrophy affects 1 in 3500 boys in Canada.

BACKGROUND INFORMATION

The sex of an individual is determined at the time of fertilization by the type of sex chromosome (X or Y) present in the sperm.

- If the sperm contains an X chromosome, the zygote will be female (XX).
- If the sperm contains a Y chromosome, the zygote will be male (XY).

Through the first six weeks of pregnancy, the embryo develops as a female. Sex differentiation occurs in the seventh week of embryonic development. Genes on the Y chromosome trigger the release of androgens that stimulate the development of male reproductive organs. Should androgens not be released, the embryo continues to develop as a female in response to the release of estrogens. Male and female reproductive organs are produced from the same embryonic tissues.

Sex-linked traits are recessive and carried on the X chromosome. Consequently, because males carry one copy of the gene and females carry two copies of the gene, sex-linked genes are expressed more often in males than in females.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

ACTIVATE

Table Conference

Organize students into groups and pose the following question:

- Henry VIII of England married six times in an attempt to have a legitimate male heir to the English throne. Recalling your knowledge of Grade 9 Science, do you think Henry was correct in blaming his wives for their inability to produce a son? (Henry did eventually have one son, who inherited the throne after his father's death.)

Remind the groups that each student must have an opportunity to speak and that all ideas should be discussed. Students should talk about a variety of possible answers, and discuss their strengths and weaknesses (Keeley).

ACQUIRE/APPLY

Table Conference—Class Discussion (U2, S1)

Engage students in a discussion of their responses to the Table Conference, reminding them to recall their knowledge from Grade 9 Science. As the discussion progresses, review with students the conventions used to denote human sex chromosomes, and introduce the specialized conventions used in sex-linked traits (e.g., X^HY, X^HX^h).

Using the Three-Minute Pause strategy, provide students with three-minute breaks after "chunks" of instruction. Students can use the breaks to summarize, clarify, and reflect on their understanding of the information with a partner or a small group in order to process information and develop their conceptual understanding. Three-minute timers or digital stopwatches can be used by students to keep track of time.

SEX-LINKED INHERITANCE

SPECIFIC LEARNING OUTCOMES

B12-1-06: Explain the basis for sex determination in humans. (GLO: D1)

Include: XX and XY chromosomes

B12-1-07: Describe examples of and solve problems involving sex-linked genes. (GLO: D1)

Examples: red-green colour-blindness, hemophilia, Duchenne muscular dystrophy . . .

Suggestion for Assessment

At the end of the lesson, distribute index cards or half sheets of paper. Ask students to describe the "muddiest point" of the lesson—that is, the ideas or parts of the lesson that were confusing or difficult to understand. Let students know you will be using the information to plan the next lesson to benefit them best. At the start of the next lesson, share with students examples of responses that informed your instructional decisions. This will help them realize that you are taking their responses seriously, and they will respond thoughtfully and with more detail in the future.

Genetics Problems—Each One Teach One (U2, G2)

Provide pairs of students with a variety of genetics problems. Students work collaboratively to solve the problems and explain their metacognitive processes to each other (they explain how they were able to determine the answers to the problems). See Appendix 1.9A: Genetics Problems 3 (BLM) and Appendix 1.9B: Genetics Problems 3 (Answer Key). The sample problems and answers provide examples of typical problems and expected solutions.

Suggestion for Assessment

Completed work can be handed in for teacher feedback. Provide feedback that is specific and descriptive, describing the performance rather than making a judgment or giving an opinion. This will help students repeat success and know what they need to improve. General comments (e.g., "Try harder next time" or "Good work") are less effective than specific and descriptive comments (e.g., "You have correctly determined the genotypes of the parents and possible offspring; however, you did not include the probability that the son will be colour-blind").

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

Sex-Linked Inheritance—Demonstrating Understanding (U1)

At the end of the lesson, pose the following question to students:

- Why are sex-linked recessive traits such as red-green colour-blindness and hemophilia more commonly found in males than in females? Explain your answer in terms of the X chromosome.

Give students five minutes to respond in their notebooks.

Suggestion for Assessment

The use of this quick formative assessment provides information about what students learned in a particular lesson. Students' responses should indicate that males inherit only one X chromosome. Therefore, if the chromosome carries an allele for a recessive disorder, the male will show the trait. Because females inherit two X chromosomes, the allele for the disorder will be masked by the dominant normal gene.

USING PEDIGREES

SPECIFIC LEARNING OUTCOME

B12-1-08: Use pedigree charts to illustrate the inheritance of genetically determined traits in a family tree and to determine the probability of certain offspring having particular traits. (GLOs: C8, D1)

Include: symbols and notations used

SLO: B12-1-08

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

The use of pedigrees to track the inheritance of a sex-linked trait was introduced in Grade 9 Science.

TEACHER NOTE

The inheritance patterns of traits can be determined by pedigree analysis. Students should be able to construct a pedigree, given family information, as well as determine the inheritance pattern of a trait from a pedigree. The inheritance patterns examined should include

- autosomal dominant conditions (e.g., Huntington disease, polydactyly)
- autosomal recessive conditions (e.g., cystic fibrosis, Tay-Sachs disease, attached earlobes)
- sex-linked recessive conditions (e.g., colour-blindness, Duchenne muscular dystrophy, hemophilia)

One commonly available pedigree is that of hemophilia in the descendents of Queen Victoria in the royal families of Europe. Point out the symbolic conventions in a pedigree chart. (i.e., male = □, female = ○, marriage line □–○).

ACTIVATE

Knowledge Chart

Provide students with a blank Knowledge Chart and have them individually record all they know in the Know Now column. Students then work with a partner to complete the Need to Know column. For more information and a sample Knowledge Chart frame, refer to *SYSTH* (pp. 9.8–9.14, 9.25).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

ACQUIRE/APPLY

Pedigree Analysis (U2, S1)

A pedigree chart is a graphic representation of genetic inheritance. Review with students the symbols used in pedigrees. Remind students that pedigree charts show only phenotype and gender. Genotypes are then determined logically.

Provide students with sample pedigrees for a variety of inheritance patterns.

Suggestion for Assessment

Students use a pedigree to determine the inheritance pattern of a trait (e.g., autosomal dominant, sex-linked recessive, autosomal recessive). In addition, when given family information, students create a pedigree illustrating the inheritance of a trait.

Using Pedigree Analysis to Solve a Genetic Mystery—Case Study (U2, P2, S1, G2, N1)

Have students work on a case study that traces the discovery of the inheritance pattern of tyrosinemia, a recessive autosomal disorder, in Quebec. See Appendix 1.10A: Using Pedigree Analysis to Solve a Genetic Mystery (BLM) and Appendix 1:10B: Using Pedigree Analysis to Solve a Genetic Mystery (Answer Key).

Regardless of whether students work on the case study individually or in small groups, encourage them to use effective reading strategies to acquire new knowledge and information from the text. This includes activating their prior knowledge before reading the case study, taking some form of notes while reading, and having an opportunity to discuss and/or reflect on what they read in the case study.

USING PEDIGREES

SPECIFIC LEARNING OUTCOME

B12-1-08: Use pedigree charts to illustrate the inheritance of genetically determined traits in a family tree and to determine the probability of certain offspring having particular traits. (GLOs: C8, D1)

Include: symbols and notations used

Resource Link

- National Center for Case Study Teaching in Science, University at Buffalo. Home Page. <http://sciencecases.lib.buffalo.edu/cs/>.

  This website provides access to a variety of case studies, which teachers can modify or adapt for classroom use, subject to the specified usage guidelines. Teaching notes and answer keys for the case studies are available free of charge. To access the answer keys, users are required to register for a password.

Suggestion for Assessment

Responses to the case study can be used as a formative assessment to determine students' levels of understanding and to guide further teaching and learning activity selection (if needed). Group work skills can be peer assessed with a checklist. Refer to Appendix 1.13: Collaborative Process—Assessment (BLM).

Hypothesizing (U2)

Ask students to hypothesize how Queen Victoria became a carrier of hemophilia when neither of her parents had hemophilia, nor was there a previous history of hemophilia in their families.

Suggestion for Assessment

A few hypotheses are possible:

- Either Victoria's mother or father developed a mutation in his or her X chromosome, which was then passed on to Victoria.
- Victoria's biological father was someone other than the man married to her mother. The mutation could have developed in his X chromosome, or in fact he had hemophilia.
- A mutation occurred in an X chromosome during the production of Victoria's egg cells.

Student responses can be used as a formative assessment to determine the level of student understanding and to guide further teaching/activity selection (if needed).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

NOTES

GENETIC TESTING

SPECIFIC LEARNING OUTCOME

B12-1-09: Discuss ethical issues that may arise as a result of genetic testing for inherited conditions or disorders. (GLOs: A3, B1, B2, C4)

SLO: B12-1-09

SUGGESTIONS FOR INSTRUCTION

BACKGROUND INFORMATION

Recent advances in genetics have raised ethical questions regarding the screening of individuals for inherited conditions and disorders. DNA screening, biochemical tests, amniocentesis, and family pedigree analysis are all tools that genetic counsellors use. Some tests may be performed on individuals, and others on fetuses.

These tools are used by genetic counsellors to analyze the risk to individuals for developing a disorder, or the risk of passing on a known inherited disorder or condition to offspring. Genetic counsellors can present options to parents so that potential risks can be avoided or reduced.

There are many issues to be considered in genetic testing. Are tests equally available to all Manitobans, or only to those with the money to pay for the tests, or to those who live in larger urban centres? Should genetic testing for a disorder be performed on individuals for whom there is no available treatment (e.g., Huntington disease)? Do third parties (e.g., insurance companies, employers) have the right to genetic test results?

ACTIVATE

Partner Speaks

Pose the following question to students:

- You know that an inherited genetic condition runs in your family. Given the opportunity, would you be tested to determine whether you carry the gene?

Students take turns discussing the question with a partner, taking careful note of their partner's thoughts on the topic. Pairs then team up, and each student shares his or her partner's thoughts with the small group. After reflecting on the small-group discussions, students record their responses to the question in their notebooks (Keeley).

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5: Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-D6: Evaluate the process used by self or others to arrive at a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Acquire/Apply

Ethical Issues—Class Discussion (U1, P2, P5, G2)

Engage the class in a discussion of the ethical issues that may arise as a result of genetic testing for inherited genetic conditions or disorders.

Resource Links

The following websites contain information about genetic testing and inherited conditions and disorders:

- Canadian Association of Genetic Counsellors. Home Page. <www.cagc-accg.ca/>.
- Canadian Hemophilia Society. Home Page. <www.hemophilia.ca/>.

GENETIC TESTING

SPECIFIC LEARNING OUTCOME

B12-1-09: Discuss ethical issues that may arise as a result of genetic testing for inherited conditions or disorders. (GLOs: A3, B1, B2, C4)

- The Canadian Society for Mucopolysaccharide and Related Diseases. Home Page. <www.mpssociety.ca/>.
  This website includes information on Tay-Sachs disease.
- Cold Spring Harbor Laboratory's DNA Learning Center. *Your Genes, Your Health*. <www.ygyh.org/>.
  Refer to this website for a multimedia guide to genetic disorders.
- Cystic Fibrosis Canada. Home Page. <www.cysticfibrosis.ca/>.
- Genetic Science Learning Center. *Learn.Genetics.* <http://learn.genetics.utah.edu/>.
- ———. "What Are Genetic Disorders?" *Learn.Genetics*. <http://learn.genetics.utah.edu/content/disorders/whataregd/>.
  This website contains tutorials and interactive animations that provide information on genetic disorders, their causes, genetic screening, and the role of genetics.
- Howard Hughes Medical Institute. *Blazing a Genetic Trail*. 1991. <www.hhmi.org/genetictrail/>.
  This website presents information on genetic diseases and screening, and includes a discussion on the ethics of genetic research.
- Huntington Society of Canada. Home Page. <www.huntingtonsociety.ca/>.
- The Sickle Cell Association of Ontario. Home Page. <www.sicklecellontario.com/>

Suggestion for Assessment

Students respond to the discussion in their notebooks and reflect on how and why their response to the Partner Speaks question changed (or did not change).

Genetic Counselling—Guest Speaker (I1, D1)

Invite a genetic counsellor or representative from an organization such as Cystic Fibrosis Canada or the Canadian Hemophilia Society to speak to the class about his or her role and the services the organization provides. Questions for the speakers should be prepared by students in advance of the visit.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5: Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-D6: Evaluate the process used by self or others to arrive at a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Suggestion for Assessment

Students summarize the highlights of the guest speaker's presentation in their notebooks. Summaries can be shared with classmates and peer assessed for content. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

GENETIC TESTING

SPECIFIC LEARNING OUTCOME

B12-1-09: Discuss ethical issues that may arise as a result of genetic testing for inherited conditions or disorders.
(GLOs: A3, B1, B2, C4)

Bioethical Dilemma—Role Play (D2, D3, D4, D5, D6, G3)

Organize students into groups of three and assign a role for each student to play (e.g., genetic counsellor, individual, partner/family member) in a scenario. Provide each group with a different scenario from the list of bioethical dilemmas presented in Appendix 1.11: Bioethical Dilemmas—Scenarios (BLM). Review with students that role-playing fosters critical thinking skills while promoting tolerance of alternative views. For more information about role-playing scenarios, refer to *SYSTH* (p. 4.18).

Students play out the scene, discuss the bioethical issue, and make a decision as to the individual's next steps in the given situation. Rotate the roles within the groups. Then provide each group with a new scenario. Repeat so that each student in the group has played a different role at least once. Have each group meet with another group to compare their decisions and share any problem areas they encountered. For more information about decision making, refer to Appendix 1.12: Decision Making (Teacher Background).

Suggestions for Assessment

See Appendix 1.13: Collaborative Process—Assessment (BLM) for a peer assessment of the group process.

Observe students using a checklist such as the following:

- Presents evidence to support arguments.
- Uses appropriate language.
- Clarifies and summarizes his or her ideas.
- Gives reasons for not agreeing with opposing points of view.
- Listens actively.

Students complete a self-assessment of their listening skills. Refer to Appendix 1.14: Self-Assessment of Listening Skills (BLM).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5: Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-D6: Evaluate the process used by self or others to arrive at a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Genetic Testing—Case Study (U2, D2, D3, I2)

Use case studies to have students examine issues related to genetic testing.

Resource Link

- National Center for Case Study Teaching in Science, University at Buffalo. Home Page. <http://sciencecases.lib.buffalo.edu/cs/>.

  This website provides access to a variety of case studies, which teachers can modify or adapt for classroom use, subject to the specified usage guidelines. Teaching notes and answer keys for the case studies are available free of charge. To access the answer keys, users are required to register for a password.

GENETIC TESTING

SPECIFIC LEARNING OUTCOME

B12-1-09: Discuss ethical issues that may arise as a result of genetic testing for inherited conditions or disorders.
(GLOs: A3, B1, B2, C4)

Suggestion for Assessment

Assessment will depend on the type of learning activity undertaken. Whatever the form of assessment used, students should be made aware of the criteria beforehand.

Letter to the Editor (P2, D1, I1, I2, I4)

Students find and read two current articles on the topic of genetic testing. When they have completed the readings, ask them to express their own point of view in a letter to the editor. For assignment details, refer to Appendix 1.15: Letter to the Editor—Writing Assignment (BLM).

Suggestion for Assessment

Determine assessment criteria in collaboration with students. For more information on the collaborative process, refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background). Assessment criteria could include

- accuracy of content
- effectiveness of communication
- use of research and references

Assess student performance in relation to the pre-established criteria and provide descriptive feedback on the quality of student work without assigning a grade. Indicate two or three next steps that students could take to improve their work, such as extending ideas, revising specific aspects of the work, or practising new skills (Gregory, Cameron, and Davies).

Examples

- Next step: Citation and documentation are a new skill we are practising. Check the MLA or APA format of your references.
- Next step: A strong ending to your letter is important. Leave your readers with the most important thought.

Give students the opportunity to revise and resubmit their work prior to assigning a grade for the assignment.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5: Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-D6: Evaluate the process used by self or others to arrive at a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

NOTES

Genetic Variability

SPECIFIC LEARNING OUTCOME

B12-1-10: Discuss the role of meiosis and sexual reproduction in producing genetic variability in offspring. (GLOs: D1, E3)

Include: crossing over and randomness

SLO: B12-1-10

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 9 Science, students were introduced to meiosis and sexual reproduction and became familiar with the terms *gamete*, *zygote*, *haploid*, and *diploid*. The emphasis in Grade 9 was placed on the importance of meiosis to maintaining chromosome number in sexual reproduction.

TEACHER NOTE

This learning outcome focuses on how genetic variability results in offspring due to meiosis and sexual reproduction. It is important that students gain a clear understanding of the consequences of meiosis. Students are not expected to memorize the names and events of the stages of meiosis.

BACKGROUND INFORMATION

Based only on the random separation of homologous chromosomes during meiosis, a person with 23 pairs of homologous chromosomes can theoretically produce about 8 million (2^{23}) different haploid gametes. Add in crossing over, and the chance of any two gametes being the same is highly unlikely. When two haploid gametes unite, the newly formed zygote contains a full set of chromosomes (i.e., the diploid number of chromosomes). Thus, meiosis allows sexual reproduction to take place.

ACTIVATE

Think-Pair-Share

Pose the following to students:

> Humans have speculated about reproduction and inheritance for thousands of years. However, they were not completely ignorant about reproduction. People have observed that in order for animals to reproduce, both a male and a female parent are required, and that the offspring usually resemble, but are not identical to, either parent.
>
> Scientists and philosophers have proposed many explanations (some fanciful) over time. Imagine that you are an observer of nature living 500 years ago. Propose a hypothesis to explain how organisms pass their traits on to their offspring. Your hypothesis should explain the observations noted above.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

Give students time to think of a hypothesis individually. Students then pair up with a partner to discuss their ideas and record their hypotheses in their notebooks.

ACQUIRE/APPLY

Why Is Meiosis Necessary?—Class Discussion (U1, G2)

Engage the class in determining chromosome number for several generations of the human life cycle if sex cells were produced by mitosis (e.g., 46 → 92 → 184 . . .). Introduce the concept of the need for a reduction division to halve the chromosome set in each gamete (without going into the details of segregation of homologous chromosomes) in order to maintain a constant number of chromosomes from one generation to the next. This will lead to a discussion of the process of meiosis.

Visualizing Meiosis (U1)

Use diagrams, videos, models, or computer animations to illustrate and describe the process of meiosis. Emphasize the role meiosis plays in producing genetic variability through the random shuffling of homologous chromosomes and crossing over, rather than focusing on the details of the phases of meiosis. The use of a note-taking strategy such as a Note Frame can help students follow a lecture and organize information. For more information, see *SYSTH* (p. 11.32).

Suggestion for Assessment

An Exit Slip provides a quick formative assessment of what students viewed as important during a particular lesson. The process for using an Exit Slip is to pose a question at the end of the lesson and give students five minutes to respond. For more information on Exit Slips, see *SYSTH* (p. 13.9).

GENETIC VARIABILITY

SPECIFIC LEARNING OUTCOME

B12-1-10: Discuss the role of meiosis and sexual reproduction in producing genetic variability in offspring. (GLOs: D1, E3)
Include: crossing over and randomness

Questions could include the following:

- Describe what you felt was the most important point made during this lesson.
- What did you learn during this lesson?
- What questions do you still have about this lesson?

For information on Exit Slips, refer to *SYSTH* (p. 13.9).

Understanding Meiosis—Chain Concept Map (U2)

Students create a Chain Concept Map (flow chart) of meiosis by linking the following terms:

- crossing over
- diploid
- haploid
- homologous chromosomes
- random shuffling of chromosomes
- reduction division
- tetrad

The concept map should include a brief description of what is happening at each step in the map. Sketches can be used to accompany the descriptions. For more information on Chain Concept Maps, refer to *SYSTH* (pp. 11.14–11.15).

Suggestion for Assessment

Assess students' Chain Concept Maps for conceptual understanding, and provide descriptive feedback on how the concept maps could be improved.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

Meiosis and Variation—Demonstrating Understanding (U1)

Pose the following question to students at the end of the lesson:

- How does meiosis lead to variation in a species?

Give students five minutes to respond in their notebooks.

Suggestion for Assessment

This learning activity provides a quick formative assessment of what students learned in a particular lesson. In their responses, students should explain that the reassortment of the chromosomes and random crossing over contribute to the large number of possible gametes formed in meiosis. This leads to differences among individual organisms, which results in variation within a species.

CHROMOSOME MUTATIONS

SPECIFIC LEARNING OUTCOMES

B12-1-11: Explain how chromosome mutations may arise during meiosis. (GLOs: D1, E3)

Include: nondisjunction

B12-1-12: Identify monosomy and trisomy chromosome mutations from karyotypes. (GLO: D1)

Examples: Down syndrome, Turner syndrome, Klinefelter syndrome . . .

SLO: B12-1-11
SLO: B12-1-12

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

Students have not studied chromosome mutation in previous science courses; however, students may know individuals with Down syndrome.

TEACHER NOTE

Be sensitive to the fact that students in your class may have a chromosome mutation, or may have a family member, neighbour, or friend with a condition.

BACKGROUND INFORMATION

Nondisjunction is the failure of chromosomes to separate correctly during meiosis. Several common syndromes are caused by nondisjunction, including the following:

- **Down syndrome:** present in about 1 in 800 children born in Canada. All persons with Down syndrome have extra genetic material associated with the 21st chromosome (trisomy 21).
- **Turner syndrome:** present in about 1 in every 2500 girls born in Canada. All girls with Turner syndrome are missing or have a damaged X chromosome (XO).
- **Klinefelter syndrome:** present in about 1 in every 1000 boys born in Canada. All boys with Klinefelter syndrome carry an extra X chromosome (XXY).

ACTIVATE

Opening Questions

Pose the following questions to students:

- The development of a complex multicellular organism from a single fertilized egg cell is one of the current areas of biological research. Genes carefully regulate the development of each individual organism. What do you think might happen if an organism had an extra regulatory gene or was missing one? What do you think might happen if an organism had an extra chromosome or was missing a chromosome?

Have students respond in their notebooks.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

ACQUIRE/APPLY

Visualizing Nondisjunction (U1)

Use models or diagrams to illustrate nondisjunction during meiosis. Flow charts can be used to show how nondisjunction affects the gametes produced by meiosis, and the chromosome monosomies or trisomies that arise after gametes fuse.

Suggestion for Assessment

Students respond to the opening questions again in their notebooks and reflect on how and why their answers to the questions changed. The responses can be used as a formative assessment to determine students' levels of understanding of nondisjunction and to guide further teaching and selection of learning activities (if needed).

Chromosome Mutations

Specific Learning Outcomes

B12-1-11: Explain how chromosome mutations may arise during meiosis. (GLOs: D1, E3)

Include: nondisjunction

B12-1-12: Identify monosomy and trisomy chromosome mutations from karyotypes. (GLO: D1)

Examples: Down syndrome, Turner syndrome, Klinefelter syndrome . . .

Concept Frame (U2)

Graphic organizers assist students in clarifying their thinking, and thereby enhance student learning. Have students complete a Concept Frame for nondisjunction. See Appendix 1.16: Concept Frame (BLM). For more information about using concept organizer frames, refer to *SYSTH* (pp. 11.22-11.25).

Suggestion for Assessment

Assess students' completed Concept Frames for conceptual understanding, and provide descriptive feedback on how they could be improved.

Chromosome-Related Syndrome—Guest Speaker (P2, I1)

Invite a local representative from a society or an organization to speak to the class about a chromosome-related syndrome and the role of the organization. Questions for the speakers should be prepared by students in advance.

Suggestion for Assessment

Following the presentation, students reflect on questions such as the following:

- What surprised you?
- What did you find interesting?
- What do you question?

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Karyotyping—Investigation (S3, S5, I4, G3)

Human karyotyping activities are relatively simple to perform. They involve the identification of the sex of an individual and a syndrome (if any) based on a photograph of a chromosome smear.

Resource Link

- Genetic Science Learning Center. *Learn.Genetics.* <http://learn.genetics.utah.edu/>.

  Students can create a karyotype and use a karyotype to predict genetic disorders using interactive animations in the *Heredity and Traits* section of this website.

Suggestions for Assessment

Specify in advance the criteria for assessment of the karyotyping investigation. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. Lab skills and group work skills can be assessed using a checklist. Refer to Appendix 1.3: Student Lab Skills (Teacher Background), Appendix 1.4A: Lab Skills Checklist—General Skills (BLM), Appendix 1.4B: Lab Skills Checklist—Thinking Skills (BLM), and Appendix 1.13: Collaborative Process—Assessment (BLM).

NOTES

Unit 1:
Understanding Biological Inheritance

Appendices

Appendix 1.1:
The Story of Gregor Mendel (BLM)

The story of Gregor Mendel and his work provides a fascinating glimpse into the nature of science. Mendel was born in 1822 and, as a young man, attended the University of Vienna. There he studied chemistry, biology, and physics, but left before graduating, probably for health reasons. He entered the Augustinian monastery in Brno, and with the support of the abbot, began his investigation of the inheritance of certain traits in pea plants (*Pisum sativum*). His choice of pea plants as the experimental subject was excellent, as peas grow and reproduce quickly, their mating can be controlled, and the plants have a number of distinct traits that are readily observed.

Over the course of eight years, Mendel conducted experiments and maintained detailed records of his results. His university training led him to design simple experiments that permitted him to observe the inheritance of one trait at a time. His use of mathematics allowed him to formulate conclusions based on his results. These conclusions are known as Mendel's laws or principles of inheritance.

Mendel's Laws or Principles of Inheritance

- **The Principle of Genes in Pairs:** Genetic characters are controlled by unit factors (genes) that exist in pairs in individual organisms and are passed from parents to their offspring. When two organisms produce offspring, each parent gives the offspring one of the factors from each pair.
- **The Principle of Dominance and Recessiveness:** When two unlike factors responsible for a single character are present in a single individual, one factor can mask the expression of another factor; that is, one factor is dominant to the other, which is said to be recessive.
- **The Principle of Segregation:** During the formation of gametes, the paired factors separate (segregate) randomly so that each gamete receives one factor or the other.
- **The Principle of Independent Assortment:** During gamete formation, segregating pairs of factors assort independently of each other.

In 1865, Mendel presented his findings in a paper entitled "Experiments in Plant Hybridization" at a meeting of the Association for Natural Research in Brno. The paper was published in the *Proceedings of the Brno Society of Natural Science* in 1866. Mendel's work was groundbreaking, not only for his discoveries in genetics, but also for his use of mathematical and statistical analysis as a means of interpreting his results.

The scientific community of the time did not seem to grasp the significance of Mendel's work. As a result, it was largely ignored. Mendel abandoned his research upon his election as abbot in 1868, due in part to his heavy workload, as well as to the lack of recognition for his research. Gregor Mendel died in 1884, never knowing whether the world would acknowledge the importance of his work. In 1900, three scientists working independently rediscovered and confirmed Mendel's laws or principles of inheritance. Hugo de Vries, Carl Correns, and Erich von Tschermak-Seysenegg gave credit to Gregor Mendel in the publications of their papers, thereby giving him the recognition he had long deserved.

Appendix 1.2: Mendel's Publication—Creative Writing Assignment (BLM)

You are to assume the role of Gregor Mendel, having just formulated your conclusions about the inheritance of traits. You are very excited about your findings and want to inform others of your findings. You will write a 500-word article for publication in a science journal, describing your experimental results and conclusions. Keep in mind that it is the year 1866, and your audience consists of scientists who subscribe to the *Proceedings of the Brno Society of Natural Science*.

Here are some tips to help you get started:

- Remember that Mendel knew nothing of genes and chromosomes, and that we use different words today in our discussions of genetics.

Mendel's Terminology (1866)	Current Terminology
unit factor	gene
purebred/true breeding	homozygous
hybrid	heterozygous
two factors that control each trait	allele

- Start your article by introducing the problem. Then describe your experimental design and the results you obtained. Finish by outlining your conclusions.
- Make your points clearly and concisely.
- Include a reference page citing the sources you used.

Appendix 1.3: Student Lab Skills (Teacher Background)

Student lab skills consist of two parts: their actions in the lab and the report that they produce. All too often, teachers have put more energy into evaluating the latter than assessing student thinking and actions during the lab. Do students understand why they are conducting the lab? Are they getting the results they expected? Do they trust their lab technique when they see others getting different results?

Consider the following suggestions when designing your assessment approach for student lab work.

Pre-lab

During the pre-lab talk, teachers traditionally outline the purpose of the lab, the procedure to be followed, methods of data collection, and safety considerations. They also pose questions to the group to check comprehension. Do students know what they are to do and why that approach is being used? Addressing the whole group continues to be the most appropriate approach for an introduction.

During the Lab

At this point, you may have an opportunity to do individual student assessment. General lab skills, such as recording observations or using equipment properly, could be marked on a checklist. You could also interview students between procedures to check the depth of their understanding. This could be done by posing a series of questions to the individual:

- How does this lab relate to what you have studied in class?
- What was the rationale behind your hypothesis?
- Are you getting the results you expected?
- Have you had any difficulties with the procedure?

This type of assessment may seem very time-consuming, but can be facilitated by using checklists and choosing to meet with a limited number of students during each lab. By using the same checklist for each student throughout the course, you could make ongoing improvements.

Post-lab

You would conduct your traditional post-lab activity. Most of the analysis would be discussed by the larger group before students did their individual write-ups. You would lead the group to an understanding of the big picture and support this with details from the group experience. After this, you might consider posing questions to certain students to check their comprehension:

- What can you conclude from your results? Give me a specific piece of evidence to support this.
- What sources of error occurred in your case?
- What would you do differently next time?

Although these questions may be written in the lab report, taking the time to discuss them with individuals allows you to probe and draw out more understanding. Again, perhaps only certain students would be questioned on a rotational basis.

Redoing the Lab

Students are often asked to identify possible sources of error. Rarely are they given the opportunity to tighten up their control variables and repeat the lab. Perhaps they want to change their approach to solving the initial problem completely and re-test. Consider the possibility of having students do one less new lab during the course and redo a lab that they have already tried. Students need to test their analytical skills by doing more than one trial. Don't we always tell them that a bigger sample size is more accurate?

A Variety of Products

Students can summarize their experiences in a lab report. You might also consider using lab frames or lab notebooks. Lab frames allow the teacher to draw out very specific responses. Lab notebooks allow students to record their work as they conduct the lab, which reflects more of the process than the product. Analyzing, answering questions, and drawing conclusions can be done after the post-lab.

The following table provides a general suggestion for a lab report. Numerous alternative formats could also be used. Refer to *Senior Years Science Teachers' Handbook* (*SYSTH*) (pp. 11.26–11.29 and 14.11–14.12) or other resources for more ideas.

Lab Report Format (Sample)	
Introduction	• purpose or question • hypothesis or prediction—may be supported by a rationale (What do students think will be found, and why?)
Methodology	• materials • methods/procedures Note: In many labs, this information will be provided. In student-designed labs, the methodology increases in importance and is developed by the student.
Results	• general observations—may include — data tables — graphs and calculations
Analysis	Include any of the following items that are appropriate to the lab: • interpretation/discussion of results • indication of whether hypothesis was supported • implications of results • linking of results to prior knowledge • answers to questions • error analysis/sources of error • summary

Appendix 1.4A: Lab Skills Checklist—General Skills (BLM)

Name ______________________________

General Skills	Expectations	Meeting Expectations	Not Yet Meeting Expectations
The student			
is prepared to conduct the lab	reads lab outline before doing the lab, creates tables, and asks questions that clarify the task instead of asking, "What do I do next?"		
sets up and uses equipment properly	chooses the correct equipment, sets up properly (e.g., ring height on ring stand), and uses equipment properly (e.g., lighting a Bunsen burner or anaesthetizing fruit flies)		
follows safety procedures	demonstrates general safety procedures as well as specifics outlined in pre-lab		
records observations	records own observations as the action is occurring, uses quantitative and qualitative approaches as directed, records in an organized fashion (e.g., uses a table or key)		
works independently (individual labs) or works cooperatively (group labs)	knows task and gets right to work or shares tasks and observations, is a good listener, and is receptive to the other students' points of view		
manages time efficiently	divides and orders tasks to meet deadlines		
cleans up adequately	leaves table and sink clean, puts away all equipment, washes tabletop, and washes hands		

Appendix 1.4B:
Lab Skills Checklist—Thinking Skills (BLM)

Name ____________________

Thinking Skills	Questions	Understanding of Lab		
		Specific	General	Limited
Knowledge/ Comprehension	• What is the purpose of doing this lab? • How does this relate to what you are studying in class? • What is the rationale for your hypothesis? • Why do you need special safety considerations for this lab? • What chemical disposal guidelines have you been given?			
Application/ Analysis	• How did you decide on this procedure? • Are you having any difficulties with this procedure? • Are you getting the results that you expected? • How would you set up a graph, diagram, or flow chart to depict these results? • Do you see a pattern in your data? • Do any data points not follow the pattern?			
Synthesis/ Evaluation	• What can you conclude from your results? • What evidence do you have to support your conclusion? Specify. • What sources of error occurred in this trial? • What would you do differently in a second trial? What would you do the same? • How do your two trial results compare?			

Appendix 1.5: Scientific Inquiry (BLM)

Introduction

Science plays an important role in daily life. Whether you investigate how changing the angles of a skateboard ramp affect the height of your jump or which type of skin cream you should buy to clear up acne, science is important to you. Learning more about how science works will enable you to use it more effectively.

People have always tried to understand the world around them. To answer the questions people may have, scientists conduct experiments or investigations that involve imagination, creativity, and perseverance. Scientists do not follow a fixed, step-by-step approach when they are investigating a question. The type of question asked will often determine the approach taken to answer it. Some investigations are mainly observational in nature, while others are more experimental. The following aspects of scientific inquiry can help you construct your own experimental investigation.

Asking a Question

A good *testable question* will often take the following form: How does ____ affect ____?
It will focus your testing to only one factor (e.g., How does the amount of sunlight affect the growth of plants? instead of What affects the growth of plants?). It will allow you to make predictions, create a plan, conduct a fair test, and make meaningful observations and conclusions.

Consider another example of a testable question: How does the application of heat affect the viscosity of a fluid? This question includes the cause (the application of heat) and the effect (viscosity of a fluid). These two portions of the testable question are called *variables*. Variables are factors that can affect an event or a process. The *independent variable* is the one variable you choose to change. The *dependant variable* changes as a result of or in response to the change in the independent variable.

Making a Hypothesis

A *hypothesis* is a suggested answer of how one variable affects the other. The hypothesis should describe the relationship between the independent and dependent variables. Often it follows an *if–then* pattern:

If the amount of heat added increases, *then* the *viscosity* will decrease.

independent variable | dependent variable

Designing the Experiment

Ensuring a Fair Test

To conduct a fair test, you must ensure that other factors that could affect the outcome of the experiment are controlled or kept the same. The variables that are not changed are called *controlled variables*. For example, in an experiment to see which sponge absorbs the most liquid, the size of the sponge used is a variable you would want to control. Samples of each of the different types of sponges to be tested could be cut to the same size. The amount of liquid each sponge absorbs could be compared fairly, with the results attributed to the type of sponge and not the size of the sponge.

Creating a Plan

The next step is to create a plan to test the hypothesis. First, you must determine what materials are needed to conduct the test. Then you create a plan or method. The method should be recorded. To continue the concept of a fair test, the test should be done several times. This is intended to ensure that results do not happen by chance, but are accurate and dependable.

Conducting the Experiment

During the experiment, it is important to follow your plan, to take accurate measurements, and to make careful observations. Your own safety and that of others should always be on your mind. To increase the accuracy and reliability of the experiment, measurements should be repeated.

Observing and Recording Data

Observations can be recorded in any of the following ways:

- written in sentences
- point-form notes
- graphs
- diagrams
- charts
- lists
- spreadsheets

Organizing and Analyzing Results

Your conclusion should explain the relationship between the independent variable and the dependent variable. Here is an example of a conclusion on an experiment that involved sunlight and plant growth.

> *In our experiment, all variables, other than the amount of sunlight, were kept constant. The geranium plants that received additional sunlight grew more than the plants that were given only limited amounts of sunlight. In the 32 days that we ran the experiment, the plants that received an additional 10 hours of sunlight a day grew an average of 3 cm, while the plants that received only limited sunlight grew an average of 1 cm. Our results support our hypothesis.*

In addition to revisiting the hypothesis, the conclusion should include the sources of error in the experiment. These would be factors that may impede the accuracy of the data. In the reflections on the process component of the conclusion, you may want to suggest ways to improve the experiment.

Implications and applications for daily use: Include an additional component to the conclusion that deals with how the experiment or concept applies to everyday living.

Appendix 1.6A: Feedback Form for Designing an Experiment (Plan) (BLM)

Name ______________________________

Proposed Experiment Title ______________________________

Criteria	Yes/No	Comments
The experimental design tests the hypothesis.		
The statement of the problem justifies the need for the experiment.		
The procedures are complete, clear, and described sequentially.		
An independent variable is clearly identified.		
The plan controls and measures the independent variable accurately.		
A dependent variable is clearly identified.		
The design ensures the dependent variable is measured accurately.		
A complete list of required materials is provided.		
The experiment includes proper controls.		
An appropriate strategy to use repeated trials and measurements is described.		
The experimental design includes appropriate safety concerns.		
Instructions are provided for proper cleanup and disposal of wastes.		

Appendix 1.6B: Rating Scale for Experimental Design and Report (BLM)

Name ____

Experiment Title _________________________________

Level 1: Not Meeting Expectations
Level 2: Approaching Expectations
Level 3: Meeting Expectations
Level 4: Exceeding Expectations

Criteria	Level			
	4	3	2	1
The experimental design tests the hypothesis.				
The statement of the problem justifies the need for the experiment.				
The procedures are complete, clear, and described sequentially.				
The plan controls and measures the independent variable accurately.				
The design ensures the dependent variable is measured accurately.				
A complete list of required materials is provided.				
The experiment includes proper controls.				
A margin of error is noted, and a thoughtful discussion for reducing error is included.				
An appropriate strategy to use repeated trials and measurements is described.				
The experimental design includes appropriate safety concerns.				
The report is neat, presentable, and well-organized.				
Appropriate vocabulary, mechanics, and complete sentences are used.				

Appendix 1.7A: Genetics Problems 1 (BLM)

1. In humans, long eyelashes are dominant; short eyelashes are recessive. A woman with long eyelashes and a man with long eyelashes have four children. One child has short eyelashes; the others have long eyelashes.
   a) List the probable genotypes of the parents.
   b) List the probable genotypes of the children.

2. Peas may have yellow or green seeds. A cross between a green seed plant and a yellow seed plant (P generation) produced all yellow seeds in the F_1 generation.
   a) Identify the genotypes of the P generation.
   b) What would the phenotype ratio of yellow seeds to green seeds be if one plant from the F_1 was crossed with the yellow seed plant from the P generation?

3. In cattle, polled (hornless) is dominant to horned. If a breeder of purebred cattle, all of which are polled, suspects that her recently purchased prize bull is heterozygous for the horned allele, how might she determine whether her suspicion is correct?

4. Cystic fibrosis is a recessive genetic disorder affecting 1 in every 2500 children born in Canada. A child with the disorder is born to a couple who show no symptoms of the disease.
   a) List the genotypes of the parents and the child.
   b) What is the chance that the next child the couple has will be a carrier of the disease?

5. In rabbits, black colour is due to a dominant gene (*B*), and brown colour to a recessive gene (*b*). Short hair is due to the dominant gene (*S*), and long hair to its recessive allele (*s*). A homozygous black, long-haired rabbit and a homozygous brown, short-haired rabbit are crossed.
   a) What would be the genotype of the F_1 generation?
   b) What would be the phenotype of the F_1 generation?
   c) If one of the F_1 rabbits was mated with a brown, long-haired rabbit, predict the phenotype and genotype ratios of the offspring.

Appendix 1.7B: Genetics Problems 1 (Answer Key)

1. a) As both parents have long eyelashes, they must both carry the dominant gene (*L*). However, in order to have a child with short eyelashes (genotype *ll*), both parents must also carry the recessive gene and, therefore, both have the genotype *Ll*.

   b) The probable genotypes of the children are listed below, using a Punnett square.

   Ll × *Ll*

	L	*l*
L	*LL*	*Ll*
l	*Ll*	*ll*

   Based on probabilities, the genotype of one child is *LL* (long eyelashes), two children are *Ll* (long eyelashes), and one child is *ll* (short eyelashes).

2. a) As the green seed colour seems to disappear in the F_1 generation, it is the recessive trait, while the yellow seed colour is the dominant trait. The genotype of the parent green seed plant will, therefore, be *yy*. The parent yellow seed must contain at least one dominant *Y* gene. Two possible yellow seed parental genotypes are possible, *YY* or *Yy*.

   YY × *yy*

	y	*y*
Y	*Yy*	*Yy*
Y	*Yy*	*Yy*

   All F_1 seeds would be yellow.

   OR

   Yy × *yy*

	y	*y*
Y	*Yy*	*Yy*
y	*yy*	*yy*

   Half the F_1 seeds would be yellow and half would be green.

   Therefore, the genotype of the parent yellow seed plant is *YY*.

b) Based on the answer in part (a), the genotype of the F_1 generation is *Yy*. The parent yellow plant is *YY*.

$YY \times Yy$

	Y	*y*
Y	*YY*	*Yy*
Y	*YY*	*Yy*

A cross between these plants would result in all yellow seeds.

3. Let purebred polled cattle (hornless) be *PP*. Horned cattle are, therefore, *pp*. The breeder can use a series of test crosses to determine the genotype of the prize bull by mating the bull with horned cows.

If the bull truly is purebred polled (*PP*), all the offspring should be polled.

$PP \times pp$

	p	*p*
P	*Pp*	*Pp*
P	*Pp*	*Pp*

All calves are polled.

If the bull is heterozygous (*Pp*), some of the offspring should have horns.

$Pp \times pp$

	p	*p*
P	*Pp*	*Pp*
p	*pp*	*pp*

Half the offspring have horns (*Pp*), and half are polled or hornless (*pp*).

4. a) Both normal parents must carry the recessive gene (*c*) for cystic fibrosis. Their genotype is, therefore, *Cc*. The child with the disease will have the genotype *cc*.

Cc × *Cc*

	C	*c*
C	*CC*	*Cc*
c	*Cc*	*cc*

b) A carrier of a disease shows no symptoms, but carries the recessive allele. Based on the above Punnett square, there is a 1 in 2 (50%) chance that the next child will be a carrier of cystic fibrosis.

5. a) Homozygous black long-haired rabbit = *BBss*.

Homozygous brown short-haired rabbit = *bbSS*.

BBss × *bbSS*

	bS	*bS*
Bs	*BbSs*	*BbSs*
Bs	*BbSs*	*BbSs*

The genotype of the F_1 generation is all *BbSs*.

b) The phenotype of the F_1 generation is all black short-haired.

c) F_1 = *BbSs* (black short-haired) × *bbss* (brown long-haired)

BbSs × *bbss*

	bs
BS	*BbSs*
Bs	*Bbss*
bS	*bbSs*
bs	*bbss*

Genotype ratio: 1 *BbSs*: 1 *Bbss*: 1 *bbSs*: 1 *bbss*

Phenotype ratio: 1 black short-haired: 1 black long-haired: 1 brown short-haired: 1 brown long-haired

Appendix 1.8A: Genetics Problems 2 (BLM)

1. A man whose blood group is A and a woman whose blood group is B have a child whose blood group is O.
   a) What are the genotypes of the three individuals?
   b) What is the probability of the couple's next child having blood group AB?
2. In radish plants, the shape of the radish produced may be long, round, or oval. Crosses among plants that produced oval radishes yielded 121 plants that produced long radishes, 243 plants that produced oval radishes, and 119 plants that produced round radishes.
   a) What type of inheritance appears to be involved? Explain your logic.
   b) What results would you expect from a cross between two long radishes?
   c) What results would you expect from a cross between two round radishes?
3. In crosses between two crested ducks, only about three-quarters of the eggs hatch. The embryos in the remaining one-quarter of the eggs develop nearly to hatching, and then die. Of the ducks that do hatch, about two-thirds are crested and one-third have no crest.
   a) What type of inheritance pattern appears to be involved? Explain.
   b) If a crested and non-crested duck are crossed, what phenotypic ratio would you expect in the ducklings? What genotypic ratio would you expect?
4. In certain cattle, the hair colour can be red (homozygous RR), white (homozygous WW), or roan, a mix of red and white hair (heterozygous RW).
   a) When a red bull is mated with a white cow, what genotypes and phenotypes of offspring could result?
   b) If one of these offspring is mated to a white cow, what genotypes and phenotypes of offspring could be produced? In what proportion?
5. How do we account for the variations of skin colour in humans?

Appendix 1.8B: Genetics Problems 2 (Answer Key)

1. a) Because the child's phenotype is type O, the genotype must be ii (recessive). Therefore, the father (type A) and mother (type B) must both carry the recessive allele. The father's genotype is I^Ai and the mother's genotype is I^Bi.

   b) The probability of the couple's next child having blood group AB is show below, using a Punnett square:

   $I^Ai \times I^Bi$

	I^B	i
I^A	I^AI^B	I^Ai
i	I^Bi	ii

   The chance of the couple having an AB (I^AI^B) child is 25% or 1 in 4.

2. a) The offspring occur in three types, classified as long, round, and oval (intermediate). This suggests incomplete dominance, with the allele for long (L) combining with round (L') to produce oval heterozygotes (LL'). This hypothesis can be tested by examining the offspring ratio. A cross of $LL' \times LL'$ will result in a ratio of 1 long to 2 oval to 1 round radishes.

   b) When two long radishes are crossed ($LL \times LL$), all the offspring will be long.

   c) When two round radishes are crossed ($L'L' \times L'L'$), all the offspring will be round.

3. a) As one-quarter of the eggs do not hatch, this suggests the presence of a lethal gene. If crested is the dominant gene (C) and non-crested is recessive (c), both the parent ducks would have the Cc genotype.

   The type of inheritance pattern that appears to be involved is shown below.

   $Cc \times Cc$

	C	c
C	CC	Cc
c	Cc	cc

   Not all the eggs carrying embryos with the CC genotype would hatch. Viable offspring would hatch in a ratio of 2 crested ducks (Cc) to 1 non-crested duck (cc).

b) If a crested duck (*Cc*) and a non-crested duck (*cc*) are bred, half the resulting ducklings would be crested (*Cc*) and the other half would be non-crested (*cc*). The genotype ratio would be 1 *Cc*: 1 *cc*. The phenotype ratio would be 1 crested duckling to 1 non-crested duckling.

4. a) The red bull's genotype is *RR*. The white cow's genotype is *WW*.

   When a red bull is mated with a white cow, the following genotypes and phenotypes of offspring could be obtained:

   RR × *WW*

	W
R	*RW*

   All the offspring have the RW genotype and will be roan in colour.

   b) When the roan offspring (*RW*) is mated with a white cow (*WW*), the following offspring would be expected:

   RW × *WW*

	W	*W*
R	*RW*	*RW*
W	*WW*	*WW*

   A ratio of 1 roan (*RW*) calf to 1 white calf (*WW*) would be expected.

5. Human skin colour is an example of a polygenic trait. It is controlled by at least four genes.

Appendix 1.9A: Genetics Problems 3 (BLM)

1. A couple has four children, all of whom are boys. What is the chance that their next child will be a girl?
2. Duchenne muscular dystrophy (DMD) is a recessive sex-linked disorder. A man and a woman who are both free of the disorder have two children. Their elder son develops DMD, while their younger son is free of the disorder.
   a) Determine the genotypes of the parents.
   b) Determine the genotypes of the children.
3. A woman (whose father was red-green colour-blind) and a man with no history of colour-blindness in his family plan to start a family. What is the chance that they will have children who are colour-blind?
4. Given the following data, determine the inheritance pattern of black, orange, and calico coat colour in cats.

   Hints: Male cats are XY and female cats are XX. Calico is a mix of orange and black fur.

Cross	Parents	Offspring
#1	black male x orange female	1 orange male: 1 calico female
#2	orange male x black female	1 black male: 1 calico female
#3	orange male x calico female	1 black male: 1 orange male: 1 orange female: 1 calico female

Appendix 1.9B: Genetics Problems 3 (Answer Key)

1. The probability of their next child being a girl is 50%. The chance of any one child being a certain sex is unaffected by the birth of previous children.

   $XY \times XX$

	X	X
X	XX	XX
Y	XY	XY

   There is a 50–50 chance of either a boy or a girl.

2. a) The father is not affected. His genotype is X^MY. To have a son with the disorder, the mother must be a carrier. Her genotype is X^MX^m.

   $X^MY \times X^MX^m$

	X^M	X^m
X^M	X^MX^M	X^MX^m
Y	X^MY	X^mY

   b) The elder son is affected by DMD. His genotype is X^mY. The younger son is free of the disorder. His genotype is X^MY.

3. The man is not colour-blind. His genotype is X^CY. The woman is not colour-blind, but inherited the gene for colour-blindness from her father. She is a carrier with genotype X^CX^c.

   $X^CY \times X^CX^c$

	X^C	X^c
X^C	X^CX^C	X^CX^c
Y	X^CY	X^cY

   There is a 50% chance that their sons will be colour-blind. None of their daughters will be colour-blind.

4. As calico is a mix of orange and black, the genes for orange and black coat colour are co-dominant. Let B = black, O = orange, and BO = calico. However, there are no male calico cats. Therefore, coat colour must be sex-linked.

   Cross #1: black male (X^BY) × orange female (X^OX^O)

	X^O	X^O
X^B	X^BX^O	X^BX^O
Y	X^OY	X^OY

   1 orange male: 1 calico female

   Cross #2: orange male (X^OY) × black female (X^BX^B)

	X^B	X^B
X^O	X^BX^O	X^BX^O
Y	X^BY	X^BY

   1 black male: 1 calico female

   Cross #3: orange male (X^OY) × calico female (X^BX^O)

	X^B	X^O
X^O	X^BX^O	X^OX^O
Y	X^BY	X^OY

   1 black male: 1 orange male: 1 orange female: 1 calico female

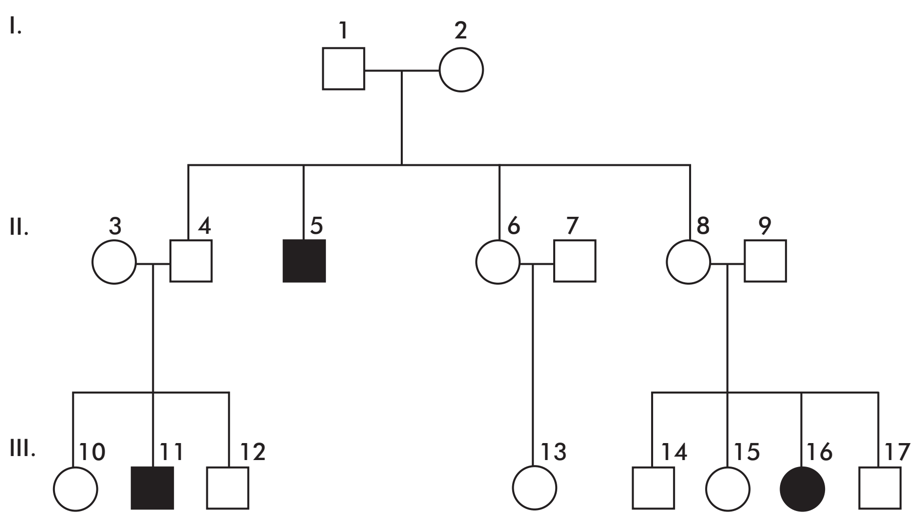
Appendix 1.10A: Using Pedigree Analysis to Solve a Genetic Mystery (BLM)

Part A

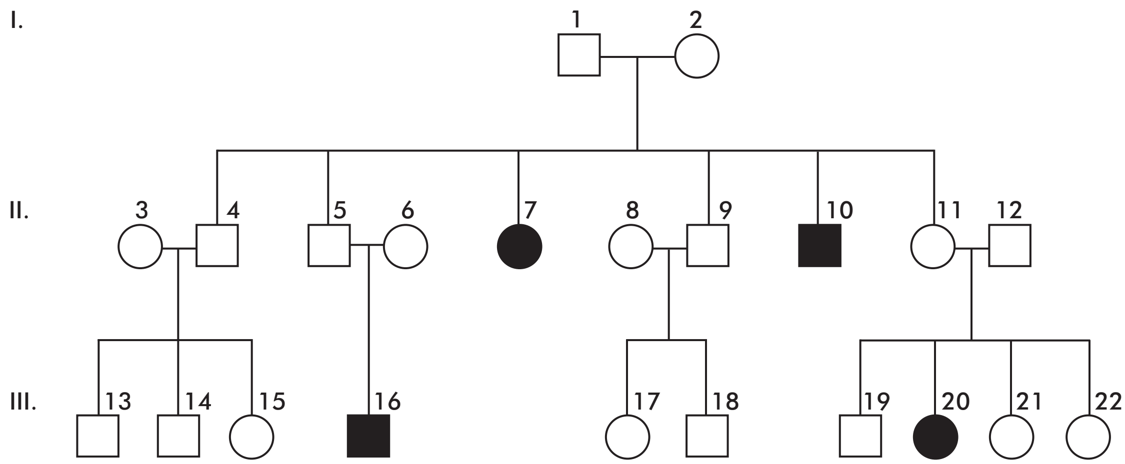
In the early 1960s, some pediatricians in the Saguenay–Lac-Saint-Jean region of Quebec noticed that some infants in the area were dying from an unknown disease. The babies seemed to be healthy when they were born, but they did not eat well or gain weight as they should. Even when the babies were admitted to hospital and fed through a tube, they did not thrive, and most died within a few months of birth. Autopsies showed that the children all died of liver failure.

Curious, doctors began to investigate what might have caused the infants' livers to fail. They found that people in the area remembered similar baby deaths in the past. The pedigree charts of two families from the Saguenay–Lac-Saint-Jean region are shown below. Individuals with the shaded symbols died of the unknown disease.

Family A



Family B



1. Examine the pedigree charts of Family A and Family B and predict how the disease is carried from one generation to the next. Explain your reasoning.
2. Predict the genotypes for the following individuals in Family A. You may be unable to determine the full genotype for all individuals.
   a) I–2
   b) II–5
   c) II–9
   d) III–12
   e) III–16
3. Predict the genotypes for the following individuals in Family B. You may be unable to determine the full genotype for all individuals.
   a) I–1
   b) II–9
   c) II–11
   d) III–14
   e) III–20
4. Individual III–10 from Family A and Individual III–19 from Family B plan to start a family together. What is the chance they could have a baby with the disease? Explain.
5. What possible reasons might there be for doctors not to have noticed the baby deaths before the 1960s, even though people in the region knew about them?

Part B

Doctors determined that the liver failure in the affected babies was caused by hereditary *tyrosinemia*, an autosomal recessive disease. These children had a biochemical defect that made them unable to produce an enzyme needed to break down tyrosine, an amino acid. As a result, tyrosine accumulated in their livers, eventually leading to liver failure and death.

The prevalence of hereditary tyrosinemia is generally quite low, affecting only about 1 in 100,000 newborns worldwide. However, in the Saguenay–Lac-Saint-Jean region in the period from 1967 to 1971, tyrosinemia affected 1 baby in 1042, and it was estimated that 1 person in 16 was a carrier for the disease (De Braekeleer and Larochelle). By 1986, the prevalence of tyrosinemia declined, affecting approximately 1 baby in 1850, with an estimated 1 person in 21 being a carrier of the disease (De Braekeleer and Larochelle).

6. What are some possible reasons for the significantly higher number of babies born with tyrosinemia in Saguenay–Lac-Saint-Jean compared with the situation worldwide?

7. What are some possible reasons for the decline in the number of babies born with tyrosinemia today in Saguenay–Lac-Saint-Jean?

Part C

By tracing family histories and constructing pedigrees, the Quebec geneticist Dr. Claude Laberge determined the Saguenay–Lac-Saint-Jean region was settled by 50 families from Charlevoix in the 1840s. Until recently, the Saguenay–Lac-Saint-Jean region was quite isolated and most people living in the region were descended from the original settlers.

All the tyrosinemia victims were traced back to one ancestral couple, Louis and Marie Gagne, who immigrated to Quebec from France in 1644 (Laberge). Either Louis or Marie must have carried the gene for tyrosinemia and passed it to some of their nine children, and many grandchildren, two of whom settled in Charlevoix. Some of their offspring later moved to the Saguenay–Lac-Saint-Jean region.

Marriages between cousins and second cousins were common in the Saguenay–Lac-Saint-Jean region, due to the small number of original settlers and lack of immigration into the area. As a result, a significant proportion of people in the region carry the tyrosinemia gene. This is an example of the *founder effect*, in which a gene mutation is observed in high frequency in a specific population, even though the mutation was originally found in a single ancestor or a small number of ancestors.

Today, genetic screening and genetic counselling are available to couples with tyrosinemia in their family histories. The gene has been located on chromosome 15. Prenatal diagnosis, newborn screening, and carrier testing are available.

8. What were some possible sources of information that Dr. Laberge might have used to construct the pedigrees?

9. Why would marriages between cousins or second cousins result in an increase in the number of babies born with tyrosinemia?

10. If you planned to have children with a partner whose family came from the Saguenay–Lac-Saint-Jean region, should you be concerned that your children may be born with tyrosinemia?

References

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Appendix 1.10B: Using Pedigree Analysis to Solve a Genetic Mystery (Answer Key)

Part A

1. The fact that one-quarter of the children are afflicted when the parents are not suggests a two-allele system involving a defective recessive allele. Since females and males were equally afflicted, it is an autosomal trait and not a sex-linked trait.

2. Let T = normal gene and t = tyrosinemia gene.
   a) Tt
   b) tt
   c) Tt
   d) $T?$
   e) tt

3. Let T = normal gene and t = tyrosinemia gene.
   a) Tt
   b) $T?$
   c) Tt
   d) $T?$
   e) tt

4. Both individuals have siblings who died of the disease. There is a 50% chance each could be a tyrosinemia carrier (Tt) and a 25% chance each could carry two normal copies of the gene (TT).
   - If both individuals are carriers ($Tt \times Tt$), there is a 25% chance they will have a child with the disease (tt).
   - If one individual is a carrier (Tt) and the other does not carry the gene (TT), there is no chance they will have a child with the disease.
   - If neither individual is a carrier of the disease (TT), there is no chance they will have a child with the disease.

5. Possible reasons for the doctors not to have noticed the baby deaths before the 1960s:
   - This was before Medicare (universal health care) was available, and a poor family could not afford to take a sick baby to a hospital.
   - Many more babies died of a variety of childhood diseases (infant mortality was higher), so these specific deaths were not noticed.
   - There were few medical specialists such as pediatricians in the Saguenay–Lac-Saint-Jean region to treat sick babies.

Part B

6. Possible reasons for the significantly higher number of babies born with tyrosinemia in Saguenay–Lac-Saint-Jean compared with the situation worldwide:
   - People didn't move into or out of the area, so the gene flow was restricted.
   - Relatives (e.g., cousins) marrying each other increased the chance of having a baby with the disease.
   - Large families resulted in more babies with the disease.
   - People didn't know what caused the babies to die, so they kept having children.
7. Possible reasons for the decline in the number of babies born with tyrosinemia today in Saguenay–Lac-Saint-Jean:
   - Genetic testing is now available for neonatal testing and carrier identification.
   - People are having smaller families.
   - Migration into and out of the area has increased (carriers move out, non-carriers move in).
   - People who have one baby with tyrosinemia don't have any more children.
   - People with tyrosinemia in their families choose not to have children.

Part C

8. Possible sources of information that Dr. Laberge might have used to construct the pedigrees include
   - hospital records
   - church records (baptisms, marriages, births, deaths)
   - gravestones
   - family interviews
   - family records (family trees)

9. Cousins share one set of grandparents. Therefore, they share some common genes.
   - When cousins marry and have children, the probability of having children with tyrosinemia increases, as does the probability of having children who are carriers.
     Example
     parents (cousins): *Tt* × *Tt*
     children: 1 *TT*: 2 *Tt* (carriers): 1 *tt* (tyrosinemia)
   - When unrelated individuals have children together, even if one parent is a carrier, the couple is unlikely to have a child with the disease.
     Example
     parents: *TT* × *Tt*
     children: 1 *TT*: 1 *Tt* (carrier)

10. Unless your family also came from the Saguenay–Lac-Saint-Jean region, it is highly unlikely that both you and your partner would carry the tyrosinemia gene. Your children should not be affected.

Appendix 1.11: Bioethical Dilemmas—Scenarios (BLM)

1. **Huntington Disease**
   You and your older brother (age 20) have just found out that your father has been diagnosed with Huntington disease. This is an incurable disorder that causes a slow progressive deterioration of the brain, resulting in death. Symptoms show up in the affected individual around age 30 to 50. Huntington disease is an autosomal dominant disorder, for which a genetic screening test has been developed. A DNA test can reveal with 100 percent certainty whether or not one will develop the disease.

2. **Down Syndrome**
   You have two healthy children from a previous marriage, but now you and your second husband would like to have a child together. You are 40 years old, and are concerned about the higher chance of having a child with Down syndrome. This condition is caused by the presence of an extra chromosome 21, which leads to intellectual disability and health problems in the affected individual. Amniocentesis is available for prenatal Down syndrome diagnosis.

3. **Hemophilia**
   You and your wife are thinking of starting a family. However, you have hemophilia, a sex-linked recessive bleeding disorder. You are being successfully treated with injections of Factor VIII, the blood-clotting enzyme your body lacks. No prenatal screening tests are available for this disorder.

4. **Cystic Fibrosis**
   You and your spouse have just found out that your 14-month-old daughter has cystic fibrosis. This is a fatal autosomal recessive disorder affecting the lungs and digestive tract. People with cystic fibrosis live shorter lives, and require daily medication and physical therapy. Your wife is pregnant again. Your doctor has informed you that genetic screening is available for prenatal cystic fibrosis diagnosis.

5. **Tay–Sachs Disease**
   When you were a child, you had a sister who died of Tay–Sachs disease. Now you and your partner want to start a family, but you have concerns about the risk of passing this recessive autosomal disorder to your children. Children born with Tay–Sachs disease suffer from progressive brain deterioration and loss of motor function. There is no treatment or cure, and death occurs in early childhood. Carriers of Tay–Sachs can be identified through a blood test, and amniocentesis can be used for prenatal Tay–Sachs diagnosis.

6. **Turner Syndrome**
   As a result of the information you have learned in this biology course, you think you may have Turner syndrome. Females with Turner syndrome are usually short in stature, tend to be weak in mathematics, and do not menstruate. They cannot have children. Your parents have never heard of this condition, caused by a missing X chromosome, and diagnosed with a blood test.

7. **Sickle-cell Anemia**
   Sickle-cell anemia is present in both your family and your partner's family. Blood tests have revealed that you are both carriers of the disease. Individuals with the disease tend to live shorter lives and suffer chronic pain, swelling in the joints, increased risk of infection, stroke, and heart attack. There is no cure for the disease, and treatment involves the use of drugs and blood transfusions. Amniocentesis can be used to diagnose sickle-cell anemia in fetuses.

Appendix 1.12: Decision Making (Teacher Background)

The decision-making process is an approach for analyzing issues and making a choice among different courses of action. Issues are often complex, with no one right answer. They can also be controversial, as they deal with individual and group values. To make an informed decision, students must understand scientific concepts involved in an issue and must be aware of the values that guide a decision. The decision-making process involves a series of steps, which may include

- identifying and clarifying the issue
- being aware of the different viewpoints and/or stakeholders involved in the issue
- critically evaluating the available research
- determining possible alternatives or positions related to an issue
- evaluating the implications of possible alternatives or positions related to an issue
- being aware of the values that may guide a decision
- making a thoughtful decision and providing justification
- acting on a decision
- reflecting on the decision-making process

In Grade 9 Science, students were introduced to the decision-making process. The issues in Grade 12 Biology involve personal and societal decisions. If students don't have much experience with the decision-making process, teachers can initiate the process with more guidance, giving students the opportunity to use this approach in a structured environment. This could be done by providing students a specific scenario or issue to study. Students would eventually become active participants in this process by choosing their own issues, doing their own research, making their own decisions, and acting on those decisions.

The decision-making process can be approached in a variety of ways. For instance, students can play the role of different stakeholders involved in an issue, work in small groups to discuss issues, or make a decision based on their own research and personal values. Students can be asked to take a stand and debate issues, or be placed in situations where they have to reach a consensus. Students should not always defend a point of view that they agree with. They should be asked to put themselves in someone else's mindset and speak from that person's point of view.

Regardless of the approach used, the following questions can guide students in the decision-making process:

- What is the issue?
- What important scientific information is needed to understand this issue?
- Where do I find this information?
- Who has a stake in this issue, and why?
- What are the possible options?
- What are the pros and cons for each of the possible options?
- What is my decision?
- What criteria were used to make this decision?

Assessment

Because there are so many different ways of approaching an issue, a variety of products or culminating tasks can result from a decision-making process, such as a town hall meeting, a round-table discussion, a conference, a debate, a case study, a position paper, a class presentation, a class discussion, and so on. Regardless of what those products or events are, the assessment should focus on the skills outlined in Cluster 0: Biology Skills and Attitudes.

For role-playing activities such as town hall meetings, round-table discussions, or conferences, assessment criteria should be related to how students are able to put themselves in the position of their stakeholder. The assessment criteria could include the following:

- The position is clearly stated.
- Evidence is presented to support arguments.
- Answers to questions are clear and aligned with the position of the stakeholder.
- The presentation is clear and organized.
- The position of the stakeholder is accurately represented.
- Personal biases are absent.

Appendix 1.13:
Collaborative Process—Assessment (BLM)

Name ____

Assessment of Collaborative Group Work

Assess your collaborative processes, using the following rating scale.

Rating Scale
4 – We were consistently strong in this area.
3 – We were usually effective in this area.
2 – We were sometimes effective in this area.
1 – We were not effective in this area. We experienced problems that we did not attempt to resolve.

Group Process	**Rating**
We were respectful of individual group members' approaches and strengths.	
We encouraged and supported each person in contributing to group discussions and decision making.	
We questioned and challenged each other's ideas, but did not make personal attacks.	
We tried to explore a wide range of ideas and perspectives prior to making decisions.	
We shared work and responsibilities equitably.	
We dealt successfully with the problem of absent or disengaged members.	
We made our decision(s) through consensus.	
We used our time productively.	

Appendix 1.14: Self-Assessment of Listening Skills (BLM)

Name ______________________________

My Listening Performance	Yes	An Area to Improve
I knew the reason for listening to help keep me focused.		
I was prepared for the presentation and knew what the speaker would talk about.		
I looked at the speaker and stayed focused.		
I kept my movement to a minimum and did not fidget or shift around.		
I often looked at the speaker, made eye contact,* nodded, or smiled.		
I listened carefully to the main points, even if I didn't agree.		
I made notes and wrote down questions or comments.		
I did not judge the speaker's ideas before he or she was finished.		
I used respectful language to ask questions or make comments.		
I listened carefully to detect exaggeration, bias, prejudice, or emotion.		
I can recall the main ideas and some details of what I heard.		
I can make comments and/or give my own opinion on what I heard.		
I assessed/evaluated the validity of the evidence the speaker presented.		

* Consider cultural appropriateness.

Additional Comments

Appendix 1.15:
Letter to the Editor—Writing Assignment (BLM)

Introduction

As you read about various issues in newspapers or magazines, you are presented with different points of view. The more well-read you are, the better you are able to formulate your own opinion on an issue. Your task is to find and read **two current articles**, written in the last two years, on the topic of genetic testing. Try to find articles with a Canadian focus. If you wish, you may read or view more articles on the topic to increase your understanding. Once you have completed your readings, express your point of view on genetic testing in a letter to the editor.

Before You Begin

1. Consider what you have been learning in class on the topic. What are your responses to some of the issues raised?
2. As you read the articles you have selected, highlight the statements you wish to react to. Address yourself to the arguments outlined in each article. You may want to summarize the arguments briefly before refuting them or reacting to them in the letter.
3. Look at sample letters to the editor from various newspapers. Consider what makes them powerful (or not).

Drafting the Letter

1. Create a strong opening. You must catch the editor's attention in order to be published. Put your introduction and main claim in the first paragraph.
2. Be persuasive. You are trying to convince someone of your point of view by reacting to the material in the articles you read. Refer to points from those articles in your letter and reference them appropriately.
3. Make your points clearly and concisely. There is little space in most newspapers for letters; the briefer you are, the more likely your letter will be published. Make your letter 200 to 300 words in length.
4. You may use rhetoric to make your point. A rhetorical question is asked for effect with no answer expected.
5. Create a strong ending by leaving your readers with the most important thought.

Appendix 1.16: Concept Frame (BLM)

Name ______________________________

Concept	Explanation

Examples

Like	Unlike

Unit 2: Mechanisms of Inheritance

Unit 2: Mechanisms of Inheritance

Specific Learning Outcomes

B12-2-01: Outline significant scientific contributions/discoveries that led to the current understanding of the structure and function of the DNA molecule. (GLOs: A2, A4, A5, B1, B2)

Include: timeline, individual contributions, multidisciplinary collaboration, and competitive environment

B12-2-02: Describe the structure of a DNA nucleotide. (GLOs: D1, D3)

Include: deoxyribose sugar, phosphate group, and nitrogenous bases

B12-2-03: Describe the structure of a DNA molecule. (GLOs: D1, D3)

Include: double helix, nucleotides, base pairing, and gene

B12-2-04: Describe the process of DNA replication. (GLOs: D1, D3)

Include: template, semi-conservative replication, and role of enzymes

B12-2-05: Compare DNA and RNA in terms of their structure, use, and location in the cell. (GLOs: D1, D3)

B12-2-06: Outline the steps involved in protein synthesis. (GLOs: D1, D3)

Include: mRNA, codon, amino acid, transcription, tRNA, anticodon, ribosome, and translation

B12-2-07: Relate the consequences of gene mutation to the final protein product. (GLOs: D1, D3)

Examples: point mutation in sickle-cell anemia, frameshift mutation in β-thalassemia . . .

B12-2-08: Discuss implications of gene mutation for genetic variation. (GLOs: D1, E1, E3)

Include: source of new alleles

B12-2-09: Investigate an issue related to the application of gene technology in bioresources. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, economic implications, a variety of perspectives, and personal/societal/global implications

B12-2-10: Investigate an issue related to the application of gene technology in humans. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, ethical and legal implications, a variety of perspectives, and personal/societal/global implications

Discovering the Structure of DNA

SPECIFIC LEARNING OUTCOME

B12-2-01: Outline significant scientific contributions/discoveries that led to the current understanding of the structure and function of the DNA molecule. (GLOs: A2, A4, A5, B1, B2)

Include: timeline, individual contributions, multidisciplinary collaboration, and competitive environment

SLO: B12-2-01

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

The historical development of our current understanding of the structure and function of DNA is an excellent example of how science operates. The challenge for teachers is to make the excitement of the scientific discoveries come alive to students and to help them gain an understanding of the nature of science.

BACKGROUND INFORMATION

Scientific contributions/discoveries that led to current understanding of the structure and function of the DNA molecule include the following:

- **Friedrich Miescher** isolated nucleic acids from the nuclei of white blood cells.
- **Phoebus Levene** showed that DNA and RNA are distinct nucleic acids, but both are composed of long chains of nucleotides.
- **Walter Sutton** and **Theodor Boveri** suggested that the genetic material of the cell is contained in chromosomes (chromosomal theory of inheritance).
- **Thomas Hunt Morgan et al.** showed that genes are linear arrays on chromosomes.
- **Frederick Griffith** performed experiments indicating that DNA is probably the genetic material of the cell.
- **Oswald Avery et al.** performed experiments indicating that DNA is probably the genetic material of the cell.
- **Alfred Hershey** and **Martha Chase** clearly showed that DNA is the genetic material of the cell.
- **Edwin Chargaff** demonstrated that the number of adenines always equals the number of thymines, and the number of cytosines always equals the number of guanines.
- **Rosalind Franklin** and **Maurice Wilkins** used X-ray crystallography to show the helical structure of DNA.
- **James Watson** and **Francis Crick** proposed the double-helix model of the DNA structure.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

Activate

Class Survey

Pose the following question to students:

- We often see diagrams and models of DNA in electronic and print media. How do you think scientists determined the structure of DNA?

Ask students to share their ideas, and record their responses on the classroom board. Use the responses to lead students in a discussion of the nature of science and the science inquiry process.

Acquire/Apply

Discovering DNA (U1)

By viewing videos and computer animations that illustrate and describe the historical development of our understanding of the structure and function of DNA, students can enhance their conceptual understanding.

The use of a note-taking strategy such as a Note Frame can help students follow a lecture and organize information (see *SYSTH*, pp. 11.32–11.33).

DISCOVERING THE STRUCTURE OF DNA

SPECIFIC LEARNING OUTCOME

B12-2-01: Outline significant scientific contributions/discoveries that led to the current understanding of the structure and function of the DNA molecule. (GLOs: A2, A4, A5, B1, B2)

Include: timeline, individual contributions, multidisciplinary collaboration, and competitive environment

Resource Links

A wealth of information on DNA can be found in a variety of multimedia formats.

- Cold Spring Harbor Laboratory's DNA Learning Center. *DNA from the Beginning*. <www.dnaftb.org/>.

  An animated primer on the basics of DNA, genes, and heredity is available on this website.

- ———. *DNA Interactive*. <www.dnai.org/>.

  This website has a timeline outlining the history of DNA science. Text biographies of contributors are available, as well as video and audio clips of interviews with researchers, including James Watson, Maurice Wilkins, and Raymond Gosling (Rosalind Franklin's graduate student). Students can follow how the researchers discovered the structure of the DNA molecule.

- The National Science Digital Library (NSDL). Home Page. <http://nsdl.org/>.

  This website has online collections of resources for teachers on DNA-related topics, including lesson plans, videos, interactives, and articles.

- Nature Publishing Group. "Double Helix: 50 Years of DNA." *Nature*. <www.nature.com/nature/dna50>.

  The science journal *Nature* has a special November 22, 2004, feature commemorating the 50th anniversary of the structure of DNA, which can be viewed online. It also contains archives (including Watson and Crick's 1953 paper describing the structure of DNA) and other features.

- Public Broadcasting Services (PBS) Online. *DNA*. <www.pbs.org/wnet/dna/>.

  This website contains a historical timeline and a 3-D DNA explorer, as well as a series on DNA, including "Episode 1: The Secret of Life," which traces the race to determine the structure of DNA.

- ———."Secret of Photo 51." *NOVA beta*. <www.pbs.org/wgbh/nova/photo51>.

  This episode investigates the role played by Rosalind Franklin in the discovery of the structure of DNA. It contains interviews, slide shows, and interactives.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

- The University of California Museum of Paleontology. "The Structure of DNA: Cooperation and Competition." 2007. *Understanding Science.* <http://undsci.berkeley.edu/article/dna_01>.

  This interactive case study describes how the work of James Watson, Francis Crick, Maurice Wilkins, and Rosalind Franklin illustrates the nature of science.

Suggestion for Assessment

During the last five minutes of the class, have students reflect on their learning by completing an Exit Slip, responding to questions such as the following:

- What do you know now that you didn't know before class today?
- What did you already know?
- What questions do you still have?

Review students' responses, looking for areas of confusion, and address the questions during the next class (formative assessment). For more information on Exit Slips, see *SYSTH* (p. 13.9).

DISCOVERING THE STRUCTURE OF DNA

SPECIFIC LEARNING OUTCOME

B12-2-01: Outline significant scientific contributions/discoveries that led to the current understanding of the structure and function of the DNA molecule. (GLOs: A2, A4, A5, B1, B2)

Include: timeline, individual contributions, multidisciplinary collaboration, and competitive environment

Discovery of DNA—Chain Concept Map (U2)

Students create a Chain Concept Map (flow chart) summarizing the information about the discovery of DNA. The flow chart should show how the developments in our understanding of DNA relied on and used the ideas and techniques developed in the work of previous scientists. For more information on Chain Concept Maps, refer to *SYSTH* (pp. 11.14–11.15).

Suggestion for Assessment

Assess students' Chain Concept Maps for conceptual understanding, and provide descriptive feedback on how the concept maps could be improved. Concept maps can also be peer assessed. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

DNA Extraction—Investigation (P1, S2, G1)

DNA extraction labs are available from many print and online sources and are relatively simple to perform. They use

- inexpensive materials (e.g., dish soap, salt [NaCl], ethanol, plant or animal tissue)
- simple equipment (e.g., beakers, test tubes, mortar and pestle, glass rods, stir sticks)

The DNA extraction technique used today is similar to that developed by Friedrich Miescher in 1869. Students today have the advantage of modern refrigeration to keep ethanol cold. The DNA produced will form long strands that can be spooled onto a glass rod or stir stick. The actual double helix structure cannot be seen with the naked eye.

Resource Links

Some online DNA extraction labs are available on the following websites.

- Agriculture in the Classroom. "DNA Extraction Lab Protocol." Rev. 11 Apr. 2011. Multimedia Educational Resource for Learning and Online Teaching (MERLOT). <www.merlot.org/merlot/viewMaterial.htm?id=423595>.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

- Fritz, Stacey. "Strawberry DNA Extraction Using Common Household Ingredients." Rev. 18 Nov. 2009. National Association of Agricultural Educators. <http://naae.ca.uky.edu:8080/clearspace_community/docs/DOC-1584;jsessionid=B6021795EF8220601201DDB13B2B85EA>.
- Genetic Science Learning Center. "DNA Extraction Virtual Lab." *Learn.Genetics.* <http://learn.genetics.utah.edu/content/labs/extraction/>.
- ———. "How to Extract DNA from Anything Living."2008. *Learn.Genetics.* <http://learn.genetics.utah.edu/content/labs/extraction/howto/>.

Suggestion for Assessment

Assess students' lab skills during the investigation using a lab skills checklist. Lab reports can be assessed as well. See Appendix 1.4A: Lab Skills Checklist—General Skills (BLM) and Appendix 1.4B: Lab Skills Checklist—Thinking Skills (BLM). Refer to *SYSTH* (pp. 11.26–11.29 and 14.11–14.12) for different ways of writing a lab report.

Discovering the Structure of DNA

SPECIFIC LEARNING OUTCOME

B12-2-01: Outline significant scientific contributions/discoveries that led to the current understanding of the structure and function of the DNA molecule. (GLOs: A2, A4, A5, B1, B2)

Include: timeline, individual contributions, multidisciplinary collaboration, and competitive environment

DNA Discovery Timeline—Research and Presentation (I1, I2, I3, I4, N1, N2)

Students (individually or in small groups) research a scientist or a team of scientists who contributed to our understanding of the structure and function of the DNA molecule. They research the following on their assigned scientist(s):

- timeline of work
- key contributions/discoveries
- contextual information (e.g., where the science research took place, biographical information on the researcher)

After they have done their research, they prepare a report of their findings and present it to the class.

Suggestions for Assessment

Students prepare and present their research outlining the significant scientific contributions/discoveries that led to our understanding of the structure and function of the DNA molecule.

Research findings can be presented in a variety of formats:

- dramatic presentation (e.g., TV interview, debate between scientists, TV news report, dramatization of the event)
- multimedia presentation (e.g., PowerPoint, video, wiki, podcast)
- oral presentation
- written report (The Jigsaw strategy could be used to share information in small groups. For more information, refer to *SYSTH*, p. 3.20.)
- visual display (e.g., poster, bulletin board, cartoon, timeline)

Presentation components may vary, depending on the type of presentation. Refer to Appendix 5.8: Checklist for Creating Visuals (BLM) for use with visuals (e.g., posters, collages, graphic organizers) and to Appendix 5.9: Oral Presentation—Observation Checklist (BLM).

Develop assessment criteria for the presentation in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. The criteria should include both content and presentation components. The content criteria should include use of key terms and understandings from the unit. See Appendix 11 in General Appendices for samples of assessment rubrics.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)
Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)
Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)
Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)
Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)
Examples: cultural and historical context, politics, economics, personalities . . .

The Nature of Science—Demonstrating Understanding (U2, N1, N2)

Have students carry out a Focused Free Writing activity by writing about their understanding of the nature of science. The following question can be used to stimulate their thinking:

> Historians debate the extent to which key individuals actually changed the course of history. Do you think the individual scientists or teams of scientists discussed in class influenced the progress of knowledge? Explain your answer.

For more information on Focused Free Writing activities, refer to *SYSTH* (pp. 13.8–13.13).

Suggestion for Assessment

Assess students’ responses for conceptual understanding of the nature of science, and provide students with written feedback.

DNA STRUCTURE

SPECIFIC LEARNING OUTCOMES

B12-2-02: Describe the structure of a DNA nucleotide. (GLOs: D1, D3)
Include: deoxyribose sugar, phosphate group, and nitrogenous bases

B12-2-03: Describe the structure of a DNA molecule. (GLOs: D1, D3)
Include: double helix, nucleotides, base pairing, and gene

SLO: B12-2-02
SLO: B12-2-03

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

Students are familiar with the terms *DNA*, *chromosomes*, and *genes* from Grade 9 Science. They have not previously studied the structure of DNA, but they may have prior knowledge gained from the media.

TEACHER NOTE

Review with students that *DNA* is the nucleic acid that stores and transmits the genetic information of a cell from one generation to the next.

BACKGROUND INFORMATION

A DNA molecule is made of building blocks known as *nucleotides*. Each DNA nucleotide consists of a five-carbon sugar (deoxyribose), a phosphate group, and one of four possible nitrogenous bases (adenine, thymine, guanine, or cytosine). The nucleotides are linked together to form chains that can vary in length and in the sequence of the nitrogenous bases. It is the sequence of nitrogenous bases that provides the genetic code of the DNA.

ACTIVATE

Brainstorming

Write the letters *DNA* on the classroom board or on an overhead projector. Ask students what comes to mind when they see these letters. Invite students to call out their responses. Accept all responses, and write them all down on the board/overhead, clustering them into categories.

Examples

- nucleotide, ATGC (adenine, thymine, guanine, cytosine), double helix = structure
- DNA fingerprinting, crime investigation TV shows = forensic uses
- Frankenfoods, genetically modified organisms (GMO), recombinant DNA = gene technology

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

ACQUIRE/APPLY

Visualizing the Structure of DNA (U1)

The use of diagrams, videos, models, or computer animations that illustrate and describe the structure of nucleotides and DNA will enhance students' conceptual understanding. Discuss with students that a nucleotide is composed of a five-carbon sugar (deoxyribose), a phosphate group, and a nitrogenous base. As there are four different nitrogenous bases (adenine, thymine, guanine, and cytosine), there are four possible nucleotides.

The use of the 10 + 2 Note-Taking strategy can assist students in developing their conceptual understanding. In using this strategy, the teacher presents information for 10 minutes and then each student summarizes or discusses the material with a partner for two minutes.

Resource Links

- Boyer, Rodney. "Interactive Animations." *Interactive Concepts in Biochemistry*. 2002. Wiley. <www.wiley.com/legacy/college/boyer/0470003790/animations/animations.htm>.

  This website provides interactive animations, tutorials, and articles on a variety of DNA-related topics.

- Cold Spring Harbor Laboratory's DNA Learning Center. *DNA from the Beginning*. <www.dnaftb.org/>.

  This website contains an animated primer on the basics of DNA, genes, and heredity.

- ———. *DNA Interactive*. <www.dnai.org/>.

  This website contains 3-D animations of the structure of the DNA molecule. Students can play an interactive game and build a fragment of DNA.

DNA STRUCTURE

SPECIFIC LEARNING OUTCOMES

B12-2-02: Describe the structure of a DNA nucleotide. (GLOs: D1, D3)
Include: deoxyribose sugar, phosphate group, and nitrogenous bases

B12-2-03: Describe the structure of a DNA molecule. (GLOs: D1, D3)
Include: double helix, nucleotides, base pairing, and gene

- Genetic Science Learning Center. *Learn.Genetics.* <http://learn.genetics.utah.edu/>.
  The *Tour the Basics* section of this website provides information, tutorials, and interactive animations on the structure of DNA, as well as DNA replication, transcription, and translation.

Suggestion for Assessment

Students complete a Concept Overview frame (see *SYSTH*, p. 11.37). Review the completed frames to assess students' comprehension, and re-teach material if necessary.

DNA Structure—Model Building (U2, G1)

DNA model building activities are readily available and are relatively simple to perform. Students work in groups and build DNA models from paper "nucleotides," clay and paper clips, beads and pipe cleaners, or other materials. If the models are constructed so that the base pairs are able to separate, the models can be used to simulate DNA replication and messenger RNA (mRNA) transcription in future lessons.

Suggestions for Assessment

Students use their DNA models to demonstrate and describe the structure of the DNA molecule to their peers, and receive feedback from peers as to their understanding of DNA structure. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

Alternatively, conduct interviews with individual students or small groups of students. The students use their models to describe and demonstrate their understanding of the structure of DNA.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

DNA as a Ladder—Analogy (U2, I4)

When examining the structure of the DNA molecule, use the analogy of a twisted ladder. The rails of the ladder correspond to the sugar-phosphate backbones of the DNA molecule, while the rungs of the ladder equate to the paired nitrogenous bases. The rails of a ladder are strong, as they lend stability to the ladder. The "rails" of DNA are held strongly together by covalent bonds, while each half of the "rung" is joined to the other by weaker hydrogen bonds. Both a ladder and DNA have complementary halves.

In order for a ladder to support the weight of the climber, all the rungs of the ladder must be of the same width. Therefore, in a DNA molecule, thymine can only bond with adenine, and cytosine only with guanine. If cytosine and thymine bonded, the rung would be too short. A bond between guanine and adenine would make the rung too long. The double-helix shape of the DNA molecule is the result of the twisting of the ladder into a corkscrew shape.

Suggestion for Assessment

While analogies can be useful when learning new concepts, they are not perfect representations. Ask students to discuss the strengths and weaknesses of the ladder analogy for describing the structure of DNA.

Examples

Strengths of Ladder Analogy	**Weaknesses of Ladder Analogy**
• double-helix shape is well represented • location of sugar-phosphate backbone is accurate • location of nucleotides is accurate	• individual nucleotides (A, T, C, G) are not represented • individual sugars and phosphates are not shown • base pairing (A-T, C-G) is not represented

DNA STRUCTURE

SPECIFIC LEARNING OUTCOMES

B12-2-02: Describe the structure of a DNA nucleotide. (GLOs: D1, D3)
Include: deoxyribose sugar, phosphate group, and nitrogenous bases

B12-2-03: Describe the structure of a DNA molecule. (GLOs: D1, D3)
Include: double helix, nucleotides, base pairing, and gene

Students' responses can be used as a formative assessment to determine their levels of understanding and to guide further teaching and learning activity selection (if needed).

DNA Replication—Representation Analysis (U2, I2)

Scientific representations are used to convey scientific ideas and come in a variety of forms (e.g., pictures, analogies, models, graphs, diagrams, charts). Because the representations are not exactly like the real thing, they have limitations that can lead to flawed conceptual understanding in students.

Provide students with a representation of DNA replication. Have them work in groups to analyze the representation to identify possible flaws or limitations. Students record their ideas and justify their reasons. For example, a picture of a DNA model is much larger than a DNA molecule is in reality; the picture may colour-code the nitrogenous bases; it may represent a thymine molecule with a T; and it may show the deoxyribose sugar with a D or an S.

Suggestion for Assessment

Ask students to suggest what could be done to improve the representation. The responses can be used as a formative assessment to determine whether students have misconceptions that are reinforced by the representation, or whether they are unable to recognize flaws or limitations in the representation.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

NOTES

DNA Replication

SPECIFIC LEARNING OUTCOME

B12-2-04: Describe the process of DNA replication. (GLOs: D1, D3)
Include: template, semi-conservative replication, and role of enzymes

SLO: B12-2-04

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Discuss the accuracy of the DNA replication process by emphasizing how one side of the molecule acts as a template for the formation of the other. The process is semi-conservative, as each new DNA molecule formed contains one-half of the original molecule.

Describe the role enzymes play in the DNA replication process. One enzyme causes the strands of DNA to separate, exposing the bases. A second enzyme recognizes the exposed bases and matches them up with free, complementary nucleotides. The enzyme then bonds the sugars and phosphates together to form the backbone of the new strand. Other enzymes "proofread" the new strands to ensure accuracy, and make corrections if required.

Emphasize that the two new DNA molecules formed in replication should be identical to the original molecule. The accuracy of the replication process maintains the integrity of genetic code from one generation of cells to the next, and from parent to offspring.

DNA replication occurs fairly quickly; as many as 4000 nucleotides per second are replicated. This helps explain why bacterial cells, under ideal conditions, can reproduce in 20 minutes.

ACTIVATE

Mechanism of DNA Replication—Thought Experiment

Pose the following question to students and ask them work in groups to develop and refine their ideas.

- When James Watson and Francis Crick developed their model of DNA structure, they immediately recognized that the complementary nature of the two sides of the helix could provide a mechanism for accurate DNA replication. Given your knowledge of DNA structure, can you propose a mechanism for accurate DNA replication?

Students record their proposed mechanism in their notebooks.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

ACQUIRE/APPLY

Visualizing DNA Replication (U1)

The use of diagrams, videos, models, or computer animations that illustrate and describe the semi-conservative replication of DNA can assist in developing students' conceptual understanding.

Using the Three-Minute Pause strategy, provide students with three-minute breaks after periods of instruction. Students use the breaks to summarize, clarify, and reflect on their understanding of the information with a partner or a small group in order to process information and develop their conceptual understanding. Students can use three-minute egg timers or digital stopwatches to keep track of time.

Resource Links

- Cold Spring Harbor Laboratory's DNA Learning Center. *DNA Interactive.* <www.dnai.org/>.

  This website contains 3-D animations illustrating the processes of replication, transcription, and translation.

- Genetic Science Learning Center. *Learn.Genetics.* <http://learn.genetics.utah.edu/>.

  The *Tour the Basics* section provides information on DNA replication, transcription, and translation in the form of tutorials and interactive animations.

- Howard Hughes Medical Institute. *BioInteractive.* <www.hhmi.org/biointeractive/>.

  Refer to this website for short video and animated clips on a variety of DNA-related topics.

Suggestion for Assessment

For the last five minutes of class, have students complete an Exit Slip, reflecting on how and why their ideas about the mechanism of DNA replication changed. Review students' responses, looking for areas of confusion, and address the questions during the next class (formative assessment). For information on Exit Slips, see *SYSTH* (p. 13.9).

DNA REPLICATION

SPECIFIC LEARNING OUTCOME

B12-2-04: Describe the process of DNA replication. (GLOs: D1, D3)
Include: template, semi-conservative replication, and role of enzymes

DNA Replication—Demonstrating Understanding (U1)

Pose the following questions to students at the end of the lesson:

- How does the structure of DNA lend itself to replication?
- Why is accuracy so important in DNA replication?

Give students five minutes to respond in their notebooks.

Suggestion for Assessment

This quick formative assessment provides information about what students learned in a particular lesson.

DNA Replication—Model Building (U2, G1)

Using their DNA models (see specific learning outcomes B12-2-02 and B12-2-03), students simulate the process of DNA replication. Two new DNA models should result, each model having one original DNA strand and one new strand.

Suggestions for Assessment

Students use their DNA models to demonstrate and describe to their peers the process of DNA replication, and receive feedback from peers as to their understanding of the process. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

Alternatively, conduct interviews with individual students or small groups of students. The students use their DNA models to describe and demonstrate their understanding of DNA replication.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

Notes

Protein Synthesis

SPECIFIC LEARNING OUTCOMES

B12-2-05: Compare DNA and RNA in terms of their structure, use, and location in the cell. (GLOs: D1, D3)

B12-2-06: Outline the steps involved in protein synthesis. (GLOs: D1, D3)

Include: mRNA, codon, amino acid, transcription, tRNA, anticodon, ribosome, and translation

SLO: B12-2-05
SLO: B12-2-06

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 8 Science, students learned about the major structures in plant and animal cells and their functions. The role of proteins in the body is discussed in Grade 11 Biology.

TEACHER NOTE

While students can generally understand the processes of DNA replication and transcription, they may have difficulty grasping the concept of translation. The use of a variety of instructional strategies can help students gain a better understanding of protein synthesis.

BACKGROUND INFORMATION

Ribonucleic acid (RNA) differs from DNA in the following ways:

- RNA contains the nitrogenous base uracil instead of thymine.
- RNA contains ribose instead of deoxyribose.
- RNA is single-stranded.
- RNA carries the genetic information found in DNA in the nucleus to the ribosomes in the cytoplasm.
- RNA comes in three forms (messenger, transfer, ribosomal), all of which are involved in translating the genetic information into the amino acid sequence of proteins.

ACTIVATE

Table Conference

Organize students into table groups. Ask the groups to recall the location and function of the following cell parts: nucleus, nuclear membrane, cytoplasm, and ribosome.

Then, pose the following question to groups:

- If the genetic code for proteins is contained in the DNA in the nucleus of the cell, and the ribosomes that construct the proteins are located in the cytoplasm of the cell, how is it possible that proteins get built?

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

Remind the groups to give each student an opportunity to speak and encourage them to discuss all ideas (Keeley). Students should talk about a variety of possible ideas, and discuss their strengths and weaknesses.

ACQUIRE/APPLY

Visualizing Protein Synthesis (U1)

The use of diagrams, videos, models, or computer animations to illustrate and describe the processes of transcription and translation can assist in the development of students' conceptual understanding.

Suggestion for Assessment

Using information gathered from instruction, students create a Chain Concept Map (flow chart) to illustrate the process of protein synthesis. Teachers can use this tool to monitor students' understanding of protein synthesis and to address any difficulties. For more information on Chain Concept Maps, see *SYSTH* (pp. 11.14–11.15).

PROTEIN SYNTHESIS

SPECIFIC LEARNING OUTCOMES

B12-2-05: Compare DNA and RNA in terms of their structure, use, and location in the cell. (GLOs: D1, D3)

B12-2-06: Outline the steps involved in protein synthesis. (GLOs: D1, D3)

Include: mRNA, codon, amino acid, transcription, tRNA, anticodon, ribosome, and translation

RNA Transcription—Model Building (U2, G1)

Using the DNA model, students simulate the process of mRNA transcription. One strand of mRNA should result.

Suggestions for Assessment

Students use their models to demonstrate and describe to their peers the process of RNA transcription, and receive feedback from peers as to their understanding of the process. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

Alternatively, conduct interviews with individual students or small groups of students. The students use their models to describe and demonstrate their understanding of RNA transcription.

DNA and RNA—Compare and Contrast (U2)

Students complete a Compare and Contrast frame to differentiate between DNA and RNA, or transcription and translation. For a Compare and Contrast template, refer to *SYSTH* (p. 10.24).

Suggestion for Assessment

Review the completed frames to verify students' comprehension, and re-teach material if necessary.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

Protein Synthesis Assembly Line—Analogy (U2, I4)

With the assistance of a few students, simulate the assembly line manufacture of "widgets," and relate this analogy to the processes of transcription and translation.

- Big Boss (DNA) has the plans for widgets.
- Supervisor (mRNA) makes a copy of the plan and carries the copy to the shop floor assembly line.
- Runners (tRNA) bring the required components (amino acids) to the assembly line from stock shelves.
- Assembler (ribosome) links the components together to form widgets (proteins).

Suggestion for Assessment

While analogies can be useful when learning new concepts, they are not perfect representations. Ask students to discuss the strengths and weaknesses of the assembly line analogy for describing protein synthesis. The responses can be used as a formative assessment to determine students' levels of understanding and to guide further teaching and/or learning activity selection (if needed).

PROTEIN SYNTHESIS

SPECIFIC LEARNING OUTCOMES

B12-2-05: Compare DNA and RNA in terms of their structure, use, and location in the cell. (GLOs: D1, D3)

B12-2-06: Outline the steps involved in protein synthesis. (GLOs: D1, D3)

Include: mRNA, codon, amino acid, transcription, tRNA, anticodon, ribosome, and translation

Translating the Genetic Code (U2)

Ask students to complete the following chart using the mRNA genetic code.

DNA Complement	DNA Template	mRNA Codon	tRNA Anticodon	Amino Acid
			GCG	
GTA				
		AAC		
				tryptophan
	AGC			

Suggestion for Assessment

Whatever the form of assessment used, students should be made aware of the assessment criteria beforehand.

Answers

DNA Complement	DNA Template	mRNA Codon	tRNA Anticodon	Amino Acid
CGC	GCG	CGC	GCG	arginine
GTA	CAT	GUA	CAU	valine
AAC	TTG	AAC	UUG	asparagine
TGG	ACC	UGG	ACC	tryptophan
TCG	AGC	UCG	AGC	serine

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

NOTES

GENE MUTATION

SPECIFIC LEARNING OUTCOMES

B12-2-07: Relate the consequences of gene mutation to the final protein product. (GLOs: D1, D3)

Examples: point mutation in sickle-cell anemia, frameshift mutation in β-thalassemia . . .

B12-2-08: Discuss implications of gene mutation for genetic variation. (GLOs: D1, E1, E3)

Include: source of new alleles

SLO: B12-2-07
SLO: B12-2-08

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 9 Science, students investigated and described environmental factors and personal choices that may lead to genetic mutation.

TEACHER NOTE

Be sensitive to the possibility that there may be students in your class who have a condition such as sickle-cell anemia or *β*-thalassemia, or who have a family member, neighbour, or friend with the condition.

Review with students the fact that only mutations that arise in sex cells can be passed on to the next generation. Somatic cell mutations cannot be passed on to offspring.

BACKGROUND INFORMATION

Refer to Appendix 2.1: Mutation (Teacher Background) for more information.

ACTIVATE

Opening Questions

Pose the following questions to students:

- What comes to mind when you hear the word *mutation*?
- Do think that a mutation could ever be a good thing? Why or why not?

Ask students to respond in their notebooks. Accept all student contributions. Note that most, if not all, student contributions will have negative connotations.

ACQUIRE/APPLY

Viewing Blood Cells—Microscope Activity (S3, I4)

Students examine slides of normal red blood cells and sickle-shaped red blood cells under a microscope and create biological drawings of the red blood cells found on the two slides.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

Suggestions for Assessment

Appendix 2.3B: Microscope Skills Checklist (BLM) can be used to assess students' microscope skills. For more information, refer to Appendix 2.3A: Microscope Skills Checklist (Teacher Background). See Appendix 2.2A: Biological Drawing (BLM) for information on creating biological drawings, and assess drawings using Appendix 2.2B: Rating Scale for Biological Drawing (BLM).

Gene Mutation and Variation (U1)

The use of diagrams, videos, models, or computer animations that illustrate and describe gene mutation and variation will enhance students' conceptual understanding.

The use of the Three-Minute Pause note-taking strategy can assist students in developing their conceptual understanding. After presenting information for a period of time, pause for three minutes to allow students to process the information.

Resource Link

- Canadian Museum of Nature. *The GEEE! in Genome*. <www.nature.ca/genome/index_e.cfm>.

  This website contains tutorials, polls, illustrations, learning activities, videos, and online games on a variety of topics such as protein synthesis, mutation, and variation.

GENE MUTATION

SPECIFIC LEARNING OUTCOMES

B12-2-07: Relate the consequences of gene mutation to the final protein product. (GLOs: D1, D3)

Examples: point mutation in sickle-cell anemia, frameshift mutation in β-thalassemia . . .

B12-2-08: Discuss implications of gene mutation for genetic variation. (GLOs: D1, E1, E3)

Include: source of new alleles

Point and Frameshift Mutations—Demonstrating Understanding (U1)

At the end of the lesson, pose the following questions to students:

- What is the difference between a point mutation and a frameshift mutation?
- Which is likely to have the greatest impact on an organism? Explain.

Give students five minutes to respond in their notebooks.

Refer to Appendix 2.4: Point and Frameshift Mutations (BLM).

Suggestion for Assessment

This quick formative assessment provides information about what students learned in a particular lesson. The responses can be used to determine students' levels of understanding and to guide further teaching and/or learning activity selection (if needed).

Simulating Mutations (U1, S5)

Provide students with the following 15-nucleotide sequence of a DNA template:

TAC GCA TGG AAT TAT

- Ask students to
  - determine the mRNA codons for the DNA (Answer: AUG CGU ACC UUA AUA)
  - determine the amino acid sequence (Answer: MET-ARG-THR-LEU-ISO)
- Next, have students, individually,
  - change one DNA nucleotide at random (i.e., simulate a point mutation)
  - determine the effect of the DNA change on the amino acid sequence

  Compare all resulting amino acid sequences in the class. Note that not all point mutations lead to changes in the amino acid sequence. This is due to the redundancies in the code; that is, a single amino acid may be specified by several codons. For example, four different codons all code for glycine.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

- Using the original DNA sequence, have students, individually,
  - add or remove one DNA nucleotide at random (i.e., simulate a frameshift mutation)
  - determine the effect of the DNA change on the amino acid sequence

  Compare all resulting amino acid sequences in the class. Note the significant change in the amino acid sequence caused by the insertion or deletion of a nucleotide. This may lead to a devastating impact on protein function and serious consequences for the organism affected.

  Refer to Appendix 2.4: Point and Frameshift Mutations.

Mutations: Good or Bad?—Class Discussion (U2, G2)

Use the examples of sickle-cell anemia and β-thalassemia to demonstrate how random changes in DNA nucleotides often result in altered proteins that do not function as well as the normal protein. Refer to Appendix 2.4: Point and Frameshift Mutations. In the discussion, note how individuals heterozygous for either condition have an advantage over homozygous dominant and recessive individuals in their resistance to malaria (heterozygous advantage).

Suggestion for Assessment

Students respond to the Opening Questions again in their notebooks and reflect on how and why their ideas about mutations have changed. Assess students' responses for conceptual understanding (formative assessment).

INVESTIGATING APPLICATIONS OF GENE TECHNOLOGY IN BIORESOURCES

SPECIFIC LEARNING OUTCOME

B12-2-09: Investigate an issue related to the application of gene technology in bioresources. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, economic implications, a variety of perspectives, and personal/societal/global implications

SLO: B12-2-09

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 9 Science, students investigated Canadian and international contributions to research and technological developments in the field of genetics. Students also discussed current and potential applications and implications of biotechnologies, including their effects upon personal and public decision making, and used the decision-making process to address a current biotechnology issue. Topics of discussion included genetic engineering, cloning, the Human Genome Project, and DNA fingerprinting.

TEACHER NOTE

Ongoing research in the field of gene technology provides both great promise and possible threat for the future. The knowledge base and its technological applications are rapidly advancing/changing. However, many ethical and practical issues surrounding the use of gene technology are hotly debated today.

Possible topics for discussion include the following:

- xenotransplantation (the transplantation of cells, tissues, or organs from one species to another)
- use of genetically modified organisms (GMOs) for food production
- patenting of transgenic organisms (e.g., seeds)
- production of drugs/vaccines using GMOs
- cloning animals, including pets
- species conservation, storing DNA
- “recreating” extinct species (e.g., woolly mammoths)

ACTIVATE

Focused Listing

Ask students to write the word *biotechnology* at the top of a piece of paper, and then list as many related terms, facts, ideas, definitions, concepts, or experiences as they can recall from previous grades (Keeley). This learning activity can also be done in small groups.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D6: Evaluate the process used by self or others to arrive at a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to acceptable practices. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Suggestion for Assessment

Scan the lists generated by students during the Focused Listing activity to assess students' understanding of vocabulary and concepts. The information gathered can be used to plan for further instruction. Should the majority of students in the class indicate little or no understanding of or familiarity with the biotechnology terms or concepts, an adjustment in the instructional plan is required to help students develop their understanding.

INVESTIGATING APPLICATIONS OF GENE TECHNOLOGY IN BIORESOURCES

SPECIFIC LEARNING OUTCOME

B12-2-09: Investigate an issue related to the application of gene technology in bioresources. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, economic implications, a variety of perspectives, and personal/societal/global implications

ACQUIRE/APPLY

Gene Technology—Headlines (U1, D1, I1)

Present the class with a headline and an article related to the application of gene technology in bioresources. Brainstorm other possible gene technology applications with students, and have each student find a headline and a related newspaper or magazine article.

Examples

Bioresource	Issue
food production	use of GMOs for food
agriculture/horticulture	patenting of transgenic organisms (e.g., seeds)
microbiology	production of drugs/vaccines using GMOs (e.g., insulin for diabetes)
animals	cloning animals, including pets
animals/plants	species conservation, storing DNA (e.g., global seed bank in Norway)
animals/plants	"recreating" extinct species (e.g., woolly mammoths)

Post the headlines on the class bulletin board. The headlines and articles will be the introduction to the student presentations later in the unit.

Suggestions for Assessment

Ask students to read the gene technology article that accompanied their headline and respond to the following questions:

- What technology or processes are outlined in the article?
- What issue is discussed in the article?
- What perspectives are presented in the article?
- What implications (societal, global, and personal) related to the issue are noted in the article?
- If the article includes visuals, what story do they tell?

Students can also make a separate list of key vocabulary used in their article.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D6: Evaluate the process used by self or others to arrive at a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to acceptable practices. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Alternatively, students could read their article and complete a Fact-Based Article Analysis or an Issue-Based Article Analysis (see *SYSTH*, pp. 11.30–11.31, 11.40–11.41).

Encourage students to use effective reading strategies to gain new knowledge from text. This includes activating their prior knowledge before the reading, taking some form of notes during the reading, and having the opportunity to discuss/reflect on what they read. For more information about strategies for reading scientific information, refer to *SYSTH* (Chapter 12).

INVESTIGATING APPLICATIONS OF GENE TECHNOLOGY IN BIORESOURCES

SPECIFIC LEARNING OUTCOME

B12-2-09: Investigate an issue related to the application of gene technology in bioresources. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, economic implications, a variety of perspectives, and personal/societal/global implications

What Is Genetic Engineering? (U1)

The use of diagrams, videos, models, or computer animations that illustrate and describe recombinant DNA techniques will enhance students' conceptual understanding.

The use of a note-taking strategy such as a Note Frame can help students follow a lecture and organize information (see *SYSTH*. p. 11.32).

Resource Links

- BIOTECanada. Home Page. <www.biotech.ca/>.
  This website provides information on the uses and benefits of biotechnology.

- Canadian Museum of Nature. *The GEEE! in Genome.* <www.nature.ca/genome/index_e.cfm>.
  This website contains tutorials, polls, illustrations, learning activities, videos, and online games on a variety of topics such as cloning and stem cells, GMOs, Canadian researchers, and genetic disorders.

- Cold Spring Harbor Laboratory's DNA Learning Center. *DNA Interactive.* <www.dnai.org/>.
  In the *Manipulation* section of this website, students can investigate recombinant DNA technologies, the ethical issues surrounding their use, and how recombinant DNA technology is used to engineer an organism to make a commercially viable product.

- Council for Biotechnology Information. *Canada: English.* <www.whybiotech.ca/>.
  This website provides information about the benefits and safety of agricultural biotechnology and its contributions to sustainable development. See the *Resources and Information* section for articles, reports, key topics, and fact sheets, including "Biotech Basics—A Guide to Plant Biotechnology in Canada."

- CropLife Canada. *Biotechnology*. <www.croplife.ca/web/english/biotechnology/>.
  This website contains the following resource:
  Crop Protection Institute of Canada. *Plant Biotechnology: A Secondary School Teacher's Resource Manual*. Etobicoke, ON: Crop Protection Institute of Canada, n.d.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D6: Evaluate the process used by self or others to arrive at a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to acceptable practices. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

- Genome Canada. Home Page. <www.genomecanada.ca/en/>.
  The *Information for the Public* section of this website discusses a range of topics in genomics research, including forestry, agriculture, and human health. *GE³LS: Genomics and Society* addresses ethical, environmental, economic, legal, and social aspects of genomic research.

Suggestion for Assessment

The use of Note Frames assists teachers in monitoring students' understanding (formative assessment). The information can be used to adjust teaching to address difficulties. Students can also exchange their Note Frames and provide each other with feedback (peer assessment).

INVESTIGATING APPLICATIONS OF GENE TECHNOLOGY IN BIORESOURCES

SPECIFIC LEARNING OUTCOME

B12-2-09: Investigate an issue related to the application of gene technology in bioresources. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, economic implications, a variety of perspectives, and personal/societal/global implications

Designing a Genetically Modified Food Crop—Poster (U2, D6, I4, G1, G3)

Students apply their understanding of the genetic engineering of crops by creating a poster outlining the steps needed to make an imaginary genetically modified food crop (e.g., jalapeanuts—peanuts with the capsaicin gene inserted, making them spicy). See Appendix 2.5: Designing a Genetically Modified Food Crop (BLM) for details.

Suggestions for Assessment

See Appendix 1.13: Collaborative Process—Assessment (BLM) for a peer assessment of the group process. Refer to Appendix 5.8: Checklist for Creating Visuals (BLM) for use with visuals such as posters, collages, graphic organizers, and so on.

Inner-City Science Centre—Field Trip (P1, S2)

The Inner-City Science Centre (ICSC), located in Niji Mahkwa School on Flora Avenue in Winnipeg, Manitoba, provides access to modern science facilities, technology, and instruction, including a fluorescent microscope and Manitoba's first flash gel system for sorting DNA. Students can take part in hands-on science experiments after school or as a field trip using top-of-the-line biotech equipment ranging from a spectrophotometer (to check the purity and concentration of plasmid DNA) to an incubating orbital shaker (to grow bacterial culture) and a centrifuge (to separate cells or bacteria).

Suggestion for Assessment

Have students complete an I Used to Think, But Now I Know reflection after the field trip to ICSC. Ask students to recall their ideas at the start of the topic discussion, and have them explain how their ideas changed or became more detailed compared to what they knew at the beginning of instruction (Keeley). Students can discuss their reflections with a partner.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D6: Evaluate the process used by self or others to arrive at a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to acceptable practices. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Gene Technologist—Guest Speaker (U2, P2, I1)

Invite a gene technologist to speak to the class. Students prepare questions in advance of the visit.

Questions may include the following:

- Who are your clients? (if appropriate)
- What background/education/experience is required to work in the field of gene technology?
- What gene technology methods are used where you work?
- What proportion of your work generates revenue? What proportion is pure research?
- Does your work provide a service to the public?

This is also a good opportunity for students to explore related careers.

INVESTIGATING APPLICATIONS OF GENE TECHNOLOGY IN BIORESOURCES

SPECIFIC LEARNING OUTCOME

B12-2-09: Investigate an issue related to the application of gene technology in bioresources. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, economic implications, a variety of perspectives, and personal/societal/global implications

Suggestion for Assessment

Students summarize the highlights of the guest speaker's presentation in their notebooks. Summaries can be shared with classmates, and peer assessed for presentation content. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

Applications of Gene Technology—Research and Presentation/ Culminating Task (P5, D1, D2, I1, I2, I3, I4)

Students investigate an aspect of the application of gene technology in bioresources, including the technology used, issues involved, perspectives, and implications. An investigation of this sort can be used as a culminating task for the unit, bringing together a number of knowledge and skills outcomes.

Suggestion for Assessment

Students prepare oral presentations, accompanied by visuals, that outline the technology, issues, perspectives, and implications related to the use of gene technology in bioresources. See Appendix 2.6A: Gene Technology Presentation (BLM), Appendix 2.6B: Gene Technology Presentation Outline—Graphic Organizer (BLM), Appendix 2.6C: Gene Technology Presentation—Teacher Background, and Appendix 2.6D: Assessment Rubric for Gene Technology Presentation (BLM).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D6: Evaluate the process used by self or others to arrive at a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to acceptable practices. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

NOTES

INVESTIGATING APPLICATIONS OF GENE TECHNOLOGY IN HUMANS

SPECIFIC LEARNING OUTCOME

B12-2-10: Investigate an issue related to the application of gene technology in humans. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, ethical and legal implications, a variety of perspectives, and personal/societal/global implications

SLO: B12-2-10

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 9 Science, students investigated Canadian and international contributions to research and technological developments in the field of genetics. Students also discussed current and potential applications and implications of biotechnologies, including their effects on personal and public decision making, and used the decision-making process to address a current biotechnology issue. Topics of discussion included genetic engineering, cloning, the Human Genome Project, and DNA fingerprinting.

TEACHER NOTE

Ongoing research in the field of gene technology provides both great promise and possible threat for the future. The knowledge base and its technological applications are rapidly advancing/changing. However, many ethical and practical issues surrounding the use of gene technology are hotly debated today.

Possible topics for discussion include the following:

- DNA fingerprinting
- cloning humans
- gene therapy
- stem cell research
- DNA sequencing
- use of DNA in tracing human origins
- "designer" babies
- genetic screening/testing

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

Activate

Role Play

Knowledge of a client's genetic screen could affect the cost of insurance. Insurance companies operate on a risk-assessment basis, with individuals who have a greater potential of developing health complications being charged more for insurance than individuals who are deemed healthy. Actuaries look at statistics to determine how much their clients should be charged. With current advancements in genetic testing, there is the potential to discriminate against those with "bad genes." It is quite possible that individuals classified as high risk may be denied the opportunity to purchase insurance. However, insurance companies must operate as a business, looking out for themselves, their shareholders, and their clients' best interests.

INVESTIGATING APPLICATIONS OF GENE TECHNOLOGY IN HUMANS

SPECIFIC LEARNING OUTCOME

B12-2-10: Investigate an issue related to the application of gene technology in humans. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, ethical and legal implications, a variety of perspectives, and personal/societal/global implications

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Divide the class into two large groups. Assign each group a different scenario and have the groups prepare their responses.

> *Scenario 1*
>
> *You represent an individual who has obtained a genetic screen and would like to purchase life insurance. Results show that you are at extremely high risk for developing cancer and hypertension (high blood pressure). However, you are currently a healthy individual. You do not smoke, you have a healthy diet, and you exercise regularly. Explain why you should be given the opportunity to purchase life insurance at a reasonable price.*
>
> *Scenario 2*
>
> *You represent an insurance company. A potential client has approached your company about the possibility of purchasing life insurance. After reviewing the individual's file, including the genetic screen, you realize the individual falls into a high-risk category. Explain to the potential client why you need to charge him or her considerably more for life insurance than a standard rate.*

Pair up students from opposite groups. Students role play their scenarios and attempt to negotiate a fair settlement. Emphasize that positive social processes must be used in the negotiations (e.g., bargaining, compromise, sensitivity). For guidelines for role-playing scenarios, refer to *SYSTH* (p. 4.18).

Following the role-playing, students analyze the negotiation process and record their reflections in their notebooks.

ACQUIRE/APPLY

Using Gene Technologies (U1)

The use of diagrams, videos, models, or computer animations that illustrate and describe applications of gene technology in humans will enhance students' conceptual understanding.

Resource Links

- Cold Spring Harbor Laboratory's DNA Learning Center. *DNA Interactive.* <www.dnai.org/>.

  In the *Applications* section of this website, students can investigate techniques of forensic analysis and use them to solve a historical puzzle, and discover how DNA science can be applied to health care and to tracing human origins.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

- Genetic Science Learning Center. *Learn.Genetics.* <http://learn.genetics.utah.edu/>.

  The *Genetic Technology* section of this website includes interactive animations and tutorials on stem cells, cloning, gene therapy, and transgenic mice. The *Virtual Labs* section features interactive labs on DNA extraction, polymerase chain reaction (PCR), gel electrophoresis, and DNA microarray.

- Howard Hughes Medical Institute. *BioInteractive.* <www.hhmi.org/biointeractive/>.

  This website contains short video and animated clips on a variety of DNA-related topics.

INVESTIGATING APPLICATIONS OF GENE TECHNOLOGY IN HUMANS

SPECIFIC LEARNING OUTCOME

B12-2-10: Investigate an issue related to the application of gene technology in humans. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, ethical and legal implications, a variety of perspectives, and personal/societal/global implications

Suggestion for Assessment

During the last five minutes of the class, have students complete an Exit Slip, reflecting on questions such as the following:

- What do you know now that you didn't know before class today?
- What did you already know?
- What questions do you still have?

Review students' responses, looking for areas of confusion, and address the questions during the next class (formative assessment). For information on Exit Slips, see *SYSTH* (p. 13.9).

Human Cloning—Research and Debate (U2, P2, P5, D2, I1)

Advise students that they will conduct research on and debate the following question:

- Should human cloning be permitted?

To help them record their research findings in preparation for the debate, students create a Fact and Opinion Recording Sheet by folding a sheet of loose-leaf paper in half and labelling one half "Fact" and the other half "Opinion." During the course of their research, students document statements that are either facts or opinions. If no opinions are stated in a given article, students can add their own opinions.

The Creative Controversy strategy can be used for this debate. This debating strategy requires students to gather arguments so that they can switch sides in a debate, and then move to consensus. For information on the Creative Controversy strategy, refer to *Senior 2 English Language Arts: A Foundation for Implementation* (Manitoba Education and Training, pp. 2–34).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

Suggestions for Assessment

Collect students' Fact and Opinion Recording Sheets and assess students on their accuracy of categorizing fact and opinion statements. Establish performance criteria with the class before the debate, and use the classroom-based criteria to create a rubric, such as Appendix 2.7: Debating Skills Rubric (BLM). Students can complete a self-assessment of their listening skills. See Appendix 1.14: Self-Assessment of Listening Skills (BLM).

INVESTIGATING APPLICATIONS OF GENE TECHNOLOGY IN HUMANS

SPECIFIC LEARNING OUTCOME

B12-2-10: Investigate an issue related to the application of gene technology in humans. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, ethical and legal implications, a variety of perspectives, and personal/societal/global implications

Selecting the Perfect Baby—Case Study (P5, D1, D2, D3, N3)

The case study "Selecting the Perfect Baby: The Ethics of 'Embryo Design'" by Julia Omarzu (available on the National Center for Case Study Teaching in Science website) considers the ethical issues of genetic manipulation and fertility treatments. Give students the opportunity to work with others to discuss and answer the questions provided. Each student should, however, record his or her individual response to the final question, as responses may vary among group members.

Encourage students to use effective reading strategies to acquire new knowledge and information from text when reading a case study. This includes activating their prior knowledge before reading the case study, taking some form of notes while reading, and having an opportunity to discuss and/or reflect on what they read in the case study.

Resource Links

- National Center for Case Study Teaching in Science, University at Buffalo. Home Page. <http://sciencecases.lib.buffalo.edu/cs/>.

  This website provides access to a variety of case studies, which teachers can modify or adapt for classroom use, subject to the specified usage guidelines. Teaching notes and answer keys for the case studies are available free of charge. To access the answer keys, users are required to register for a password.

- Omarzu, Julia. "Selecting the Perfect Baby: The Ethics of 'Embryo Design.'" 18 Aug. 2002. *Case Collection*. National Center for Case Study Teaching in Science. <http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp? case_id=347&id=347>. Case Teaching Notes are available at <http://sciencecases.lib.buffalo.edu/cs/files/genetic_selection_notes.pdf>.

Suggestions for Assessment

Observe students as they discuss the issues raised in the case study. The topic can be emotionally charged. Note the willingness of students to listen to others and be open to others' opinions.

Assessment can be focused on a number of areas, such as group work. It can involve self-assessment and peer assessment, as well as a written response to the questions and a personal reflection.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

The Guy Paul Morin Case—Microtheme (U2, I1, I2, I3, I4, N2)

Microthemes are short writing assignments designed to help students learn the material by looking at it in a different way (Martin, "Writing 'Microthemes' to Learn Human Biology"). They require more than simply reading the text or articles and memorizing notes. Each microtheme addresses a specific problem, allowing the writer to illustrate his or her understanding. For more information on microthemes, refer to Appendix 2.8A: Microthemes (Teacher Background).

Have students complete the assignment outlined in Appendix 2.9: Gene Technology Microtheme Assignment (BLM).

INVESTIGATING APPLICATIONS OF GENE TECHNOLOGY IN HUMANS

SPECIFIC LEARNING OUTCOME

B12-2-10: Investigate an issue related to the application of gene technology in humans. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, ethical and legal implications, a variety of perspectives, and personal/societal/global implications

Resource Links

- National Association of Criminal Defense Lawyers (NACDL). <www.nacdl.org/>.
- ———. *The Champion*. <www.nacdl.org/public.nsf/freeform/championmag?OpenDocument>.

  For an overview of the Guy Paul Morin case, see the following article:

  King, Jack. “The Ordeal of Guy Paul Morin: Canada Copes with Systemic Injustice.” *The Champion* (Aug. 1998): 8. Available on the NACDL website at <www.nacdl.org/public.nsf/championarticles/19980808?opendocument>.

Suggestion for Assessment

Discuss assessment criteria with the class. Refer to Appendix 2.8B: Microthemes—First Draft Checklist (BLM) and Appendix 2.8C: Microthemes—Final Draft Assessment (BLM).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P5: Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

NOTES

NOTES

Unit 2: Mechanisms of Inheritance

Appendices

Appendix 2.1: Mutation (Teacher Background)

Mutation is the only mechanism by which new genetic material enters the gene pool. Often, mutations involving base substitutions are neutral or without effect. For example, redundancies in the genetic code mean that a single amino acid may be specified by several codons. Therefore, a change in one base may not result in a change of amino acid. Also, the substitution of one amino acid for another may not affect the function of an enzyme, as the enzyme's active site is not changed.

In general, random changes in DNA nucleotides result in altered proteins that do not function as well as the normal protein. Hemoglobin molecules in individuals with severe (homozygous) forms of sickle-cell anemia and thalassemia cannot carry oxygen as efficiently. Sickle-cell anemia is an example of a point mutation, the substitution of one DNA nucleotide for another, so that one codon may code for a different amino acid. An example of a frameshift mutation is β-thalassemia, which involves the deletion or addition of nucleotides, so that every codon beyond the point of insertion or deletion is read incorrectly during translation.

Occasionally, however, the altered protein functions more effectively, or works in a way that gives a selective advantage to its possessor. This is how new alleles arise and contribute to evolution. In the case of sickle-cell anemia and thalassemia, individuals heterozygous for the condition are only mildly affected by anemia. However, they have a higher resistance to malaria than do those who have homozygous normal hemoglobin. This is an example of heterozygous advantage in which individuals with two different alleles of a gene have an increased survival rate.

Appendix 2.2A: Biological Drawing (BLM)

Making a Biological Drawing

Use the following criteria for making a biological drawing:

1. What to Use
   a) Use a sharp pencil.
   b) Use a clean sheet of unlined paper.
2. What to Draw
   a) Draw only what you see.
   b) Draw only what is necessary.
3. How to Draw
   a) Centre your diagram.
   b) Draw a large enough diagram to show details clearly (approximately half a page).
   c) Make your proportions accurate.
4. Showing Depth
   a) Do not shade.
   b) Show depth with stippling.
5. Label Your Drawing
   a) In your title, include the name of the slide, the total magnification, the date observed, the field diameter, and the size of the object.
   b) Label specific information. Labels should be printed, written horizontally, and placed to the right of the drawing.
   c) Use a ruler to draw labelling lines and do not cross the lines.

Appendix 2.2B:
Rating Scale for Biological Drawing (BLM)

Name ____________________

Title of Drawing or Lab ____________________

	Possible Points	Self-Assessment	Teacher Assessment
1. Tools/Material (What to Use) a) Used sharp pencil. b) Used clean sheet of unlined paper.			
2. Content (What to Draw) a) Drawing includes only what was observed. b) Drawing includes only what is necessary.			
3. Approach (How to Draw) a) Diagram is centred. b) Diagram is large enough to show details clearly. c) Proportions are accurate.			
4. Showing Depth a) Did not shade. b) Used stippling to show depth.			
4. Labelling (Label Your Drawing) a) Title includes the name of the slide, the total magnification, the date observed, the field diameter, and the size of the object. b) Specifics on diagram are labelled. c) Labelling lines are drawn with a ruler and do not cross.			
Totals			

Comments

Appendix 2.3A: Microscope Skills Checklist (Teacher Background)

When using the Microscope Skills Checklist, use one page per student and use it throughout the course. Either a check mark or a date reference can be placed in the appropriate column to indicate whether the student is *meeting* or *not yet meeting expectations*. Anecdotal comments can be recorded in the space provided below the table (be sure to include a date with the comment).

While these skills could be assessed through a pencil-and-paper task, that approach would not provide feedback on the student's *skill level* in performing the required tasks. It would only provide information as to a student's *knowledge* of what the steps/procedures are. Performance tasks and observational assessment should be used whenever possible.

Appendix 2.3B: Microscope Skills Checklist (BLM)

Name ______________________________

Skills	Meeting Expectations	Not Yet Meeting Expectations
1. General Microscope Skills a) Handles and cares for microscope properly. b) Selects proper magnification to see the object (i.e., cell or tissue). c) Uses only fine focus on medium and high power. d) Watches from the side when bringing object and lens together. e) Uses diaphragm and/or mirror to adjust light properly.		
2. Proper Technique to Focus Object under Various Magnifications (i.e., parfocal) a) Starts on low power with coarse adjustment. b) Centres object. c) Adjusts fine focus. d) Moves up to medium or high power using only fine focus.		
3. Preparing a Wet Mount Slide a) Places specimen and drop of water on slide. b) Lowers cover slip at a 45° angle.		
4. Staining a Wet Mount Slide a) Prepares the wet mount slide. b) Places a drop of stain on one side of the cover slip. c) Draws through with a paper towel.		
5. Oil Immersion Technique (Optional) a) Properly focuses slide on high power. b) Swings lens to the side. c) Puts drop of oil on slide. d) Positions oil immersion lens and focus.		
6. Technical Skills a) Determines total magnification. b) Determines object size.		

Comments (include date)

Appendix 2.4: Point and Frameshift Mutations (BLM)

Point mutation: substitution of one DNA nucleotide for another, so that one codon may code for a different amino acid.

Normal beta hemoglobin chain

ATG GTG CAC CTG ACT CCT **GAG** GAG AAG TCT GCC ACT GCC CTG TGG GGC AAG GTG AAC GTG GAT GAA GTT GGT . . .
Val His Leu Thr Pro **Gln** Glu Lys Ser Ala Thr Ala Leu Trp Gly Lys Val Asn Val Asp Gln Val Gly . . .

Sickle-cell beta hemoglobin chain

ATG GTG CAC CTG ACT CCT **GTG** GAG AAG TCT GCC ACT GCC CTG TGG GGC AAG GTG AAC GTG GAT GAA GTT GGT . . .
Val His Leu Thr Pro **Val** Glu Lys Ser Ala Thr Ala Leu Trp Gly Lys Val Asn Val Asp Gln Val Gly . . .
^

Substitution of thymine for adenine causes coding for valine instead of glutamine. This causes the beta hemoglobin chain to fold incorrectly, producing defective hemoglobin. The red blood cells are distorted into a sickle or crescent shape and their oxygen-carrying capacity is reduced.

Frameshift mutation: deletion or addition of nucleotides, so that every codon beyond the point of insertion or deletion is read incorrectly during translation.

Normal beta hemoglobin chain

ATG GTG CAC CTG ACT CCT GAG GAG **AAG** TCT GCC ACT GCC CTG TGG GGC AAG GTG AAC GTG GAT GAA GTT GGT . . .
Val His Leu Thr Pro Gln Glu Lys Ser Ala Thr Ala Leu Trp Gly Lys Val Asn Val Asp Gln Val Gly . . .

β-Thalassemia hemoglobin chain

-AA
ATG GTG CAC CTG ACT CCT GAG GAG G TCT GCC ACT GCC CTG TGG GGC AAG GTG AAC GTG GAT GAA GTT GGT . . .

ATG GTG CAC CTG ACT CCT GAG GAG GTC TGC CGT TAC TGC CCT GTG GGG CAA GGT GAA CGT GGA TGA
Val His Leu Thr Pro Gln Glu Val Cys Arg Tyr Cys Pro Val Gly Gln Gly Glu Arg Ala Stop
^ ^

Missense (change in the codons) from point of nucleotide deletion creates an early polypeptide chain termination. The beta hemoglobin molecule is short, producing a defective hemoglobin molecule. The red blood cells are smaller than normal and their oxygen-carrying capacity is reduced.

References

Carnegie Institution for Science. "Sickle Cell Anemia." Available at <http://carnegiescience.edu/first_light_case/horn/lessons/sickle.html> (17 Sept. 2010).

Orkin, Stuart H., and Sabra C. Goff. "Nonsense and Frameshift Mutations in β^{o}-Thalassemia Detected in Cloned β-Globin Genes." *The Journal of Biological Chemistry* 256.19 (1981): 9782–84. Available online at <www.jbc.org/content/256/19/9782. full.pdf+html?sid=21c12b48-7a1d-434b-867e-4c219a3d534e> (6 Apr. 2011).

Appendix 2.5: Designing a Genetically Modified Food Crop (BLM)

Introduction

Imagine that you are working for a gene technology company that focuses on developing genetically modified food crops. You and your colleagues (classmates) have been assigned the task of designing potential new food crops. You will be divided into teams of three or four by your manager (teacher) to brainstorm ideas for potential new food crops. One of your team's ideas for a new food crop will be presented to the company in the form of a poster.

Purpose

You will apply your understanding of genetic engineering of crops by creating a poster outlining the steps of the genetic engineering process, as well as the potential benefits and limitations of your new genetically modified food crop.

Materials

- poster paper
- markers
- other items you want to include on your poster (e.g., diagrams, pictures)

Procedure

1. Your manager will divide you into teams of three or four.
2. In your teams, brainstorm ideas for a new genetically modified food crop.
3. Choose one of your team's ideas, and outline the steps necessary to create the new crop.
4. Create a poster that outlines the steps of the process to create the new genetically modified food crop.
   a) Explain, and include drawings of, each step in the genetic engineering process.
   b) List the potential benefits and limitations of the new food crop.
5. Each team will use their poster to present their new genetically modified food crop idea to their colleagues and manager.

Appendix 2.6A: Gene Technology Presentation (BLM)

You will now prepare a five- to seven-minute oral presentation, accompanied by visuals, that outlines the technology, issues, perspectives, and implications related to the use of gene technology in bioresources.

Review the headlines presented throughout the Mechanisms of Inheritance unit and the issues discussed in class. Which gene technology issue interests you the most? On which issue can you find adequate information for your presentation (e.g., current, covers various points of view, catchy visuals)?

Prepare a presentation that outlines the gene technology, and the issues, perspectives, and implications related to its use. Focus on the varied points of view. What are the concerns of each side? You must use two current sources of information (within the last two years). Your presentation will have two parts, visual and oral. The visual may take a variety of forms (e.g., PowerPoint, model, poster, demonstration) and is meant to outline the key ideas of your presentation. You must give the details in your five- to seven-minute oral presentation.

In the oral presentation, introduce your topic, the type of technology involved, and the selected issue, and then discuss two differing perspectives on the issue, as well as the societal, global, and personal implications. Back up your points with facts from your research. For more information, see Appendix 2.6B: Gene Technology Presentation Outline—Graphic Organizer (BLM). Throughout the unit, you have learned how genes work in organisms and how we can manipulate that knowledge to our advantage. Use the facts and vocabulary of the unit in your presentation.

Appendix 2.6B:
Gene Technology Presentation Outline—Graphic Organizer (BLM)

Name ____

Your teacher must approve your presentation outline before you proceed. Bring at least two resources to review with your teacher.

Topic
Type of Technology
Issue
Perspective A
Perspective B
Possible Actions
Societal Implications
Global Implications
Personal Implications
Other Key Points
Type of Visual Presentation

Appendix 2.6C: Gene Technology Presentation (Teacher Background)

Introduction

Present a headline from a magazine or newspaper article about the application of gene technology in bioresources. Brainstorm possible topics with students. Schedule deadlines for finding headlines and presentation dates. You can expect that students may bring a variety of headlines that may not fit the topic, or will be factual and not issue-based. This is a good opportunity to discuss the dynamic nature of biology, even if the article is not suitable for the presentation.

Sample Presentation Outline

Topic: Genetically Modified Food

Type of Technology
Genes do not always work when spliced into foreign surroundings; they need help to function. Biotechnologists do not simply insert genes; instead, they use promoters. A promoter is a gene fused to a DNA section from a pathogenic virus that promotes gene expression. The gene then functions, but not in its natural way. It acts like an invading virus.

Issue
Do the benefits of using genetically modified foods outweigh the detriments?

Perspective A
Traditional breeding methods are slow and labour-intensive. Through genetic modification, organisms can be given a desirable gene in one generation. That gene can be from similar or distantly related species. For example, INGARD®, genetically modified (GM) cotton, contains a gene from a soil bacterium that makes it more resistant to a caterpillar pest. The economic benefit of using the GM cotton is that it requires less herbicide use. The crop may also be healthier. The economic detriment of using the GM cotton is that the seeds are much more expensive to buy.

Perspective B
The major arguments against GM foods are the potential risks to the environment and possible risks to humans. There is a concern that the GM gene will spread into the environment, as evidenced by the case of contamination of local crops by Roundup Ready® Canola in Saskatchewan in the late 1990s. Will we see new allergic reactions, exposure to toxins, and new diseases emerge by using viral and bacterial vectors to transfer genes?

Possible Actions

- Grow GM crops (recognizing limitations on distribution).
- Use some GM crops only for animal feed.
- Do not use GM crops without further testing.

Societal Implications

- A healthier human population from improved food sources (e.g., rice that contains Vitamin A that helps prevent blindness)

Global Implications

- Accessibility of GM crops (e.g., can everyone afford to grow them?)
- Growing GM crops in marginal areas (e.g., developing salt-tolerant crops)
- Growing GM crops over a larger range (e.g., frost/drought-resistant crops such as frost-tolerant strawberries)

Personal Implications

- Healthier food sources (e.g., potatoes that absorb less oil when fried are being developed)
- Choosing whether or not to grow GM crops

Other Key Points

- Monsanto versus Schmeiser court case over the use of Roundup Ready Canola

Type of Visual Presentation

- PowerPoint
- Pictures of GM foods, pictures of canola, focus on how genes are spliced, picture of a label for GM food

Appendix 2.6D: Assessment Rubric for Gene Technology Presentation (BLM)

Name ____________________

Criteria	Exemplary 4	Accomplished 3	Developing 2	Beginning 1
Content	• shows excellent depth of understanding of topic • clearly identifies issue, two perspectives, and implications	• shows good understanding of topic • identifies issue, two perspectives, and implications	• shows basic understanding of topic • somewhat identifies issue, two perspectives, and implications	• shows minimal understanding of topic • poorly identifies issue, two perspectives, and implications
Organization	• presentation is very well organized, logical, and interesting	• presentation is organized, logical, and interesting	• presentation shows signs of organization, but some parts do not fit the topic	• presentation shows poor organization and lack of preparation
Visuals	• makes excellent use of visuals • visuals support the key ideas well	• makes good use of visuals • visuals support the key ideas	• makes adequate use of visuals • visuals support the key ideas somewhat	• makes poor use of visuals • visuals do not support the key ideas
Delivery	• words are clear, and spoken at correct speed • voice is loud enough to be heard easily	• most words are clear, and often spoken at correct speed • voice is loud enough to be heard	• some words are clear, but at times spoken too quickly • voice sometimes cannot be heard	• many words are unclear, and spoken too quickly or too slowly • voice often cannot be heard
Audience	• audience is very involved and interested	• audience is involved and interested	• audience is somewhat involved and interested	• audience is not involved or interested
Comments				

Appendix 2.7: Debating Skills Rubric (BLM)

Name ____

Criteria	Exemplary 4	Accomplished 3	Developing 2	Beginning 1
Organization of Opening Statement	• always maintains focus on the topic	• maintains focus on the topic, with few exceptions	• does not consistently maintain focus on the topic	• does not maintain focus on the topic
Use of Evidence to Support Claims	• always uses evidence to support claims	• usually uses evidence to support claims	• rarely uses evidence to support claims	• does not use evidence to support claims
Persuasiveness	• arguments are always clear and convincing	• arguments are generally clear and convincing	• arguments are sometimes clear and convincing	• arguments are not clear and/or not convincing
Teamwork	• always uses team members effectively	• usually uses team members effectively	• sometimes uses team members effectively	• does not use team members effectively
Organization of Closing Statement	• always responds with points that are specific to the topic	• usually responds with points that are specific to the topic	• sometimes responds with points that are specific to the topic	• does not respond with points that are specific to the topic

Appendix 2.8A: Microthemes (Teacher Background)

Microthemes are writing assignments designed to help students learn the science material by looking at it in a different way (Martin, "Writing 'Microthemes' to Learn Human Biology"). This involves more than simply reading the textbook or memorizing notes. Students must examine a particular case study and interpret what is going on. Afterwards, they express their ideas in a short, written work. Their writing must be concise, detailed, and accurate.

Each microtheme is based on a case study related to the unit of study and poses a question or gives a particular task. A microtheme may require specific thinking skills (e.g., create an analogy, analyze data, write from a particular point of view, examine more than one point of view).

Assessment of microtheme tasks is usually approached differently than assessment of traditional classroom activities. Microtheme tasks require higher-level thinking. It is preferable to have students complete only a few microthemes but to rework them until they have met the preset standard. This usually requires a minimum of two drafts. The standard relates to science content, task completion, and communication, and may reflect a particular grade (e.g., 70 percent). Editing of the first (and subsequent) draft may be done by the teacher or by other students in the class, with the feedback provided being formative in nature.

Students may be given the opportunity to count microthemes for a greater value, and then devalue other categories (e.g., tests, if students exhibit test anxiety). Microthemes might also be given to students who need to be absent for a period of time (e.g., due to illness, vacations) but still need to work with the material.

Appendix 2.8B: Microthemes—First Draft Checklist (BLM)

(For Teacher or Peer Editing)

Name ______________________	Microtheme ______________________
Science Content ❑ Accurate ❑ Complete/sufficient detail provided ❑ Uses appropriate scientific vocabulary ❑ Uses appropriate examples and/or diagrams – *detail should reflect high-school level* – *use of biological terms enhances the writing (correct use of terms, doesn't detract from flow)*	**Feedback**
Task Completion ❑ Task completed effectively (e.g., explanation given, question answered, argument made, point of view represented) – *last paragraph should provide a concise summary of problem and solution, statement of recommendation, etc.* **Provide additional criteria related to specific microtheme:** ❑ ❑ ❑	**Feedback**
Communication ❑ Communicates effectively (spelling, grammar, flow) ❑ Format or voice appropriate to the task or audience – *clear sentence structure* – *writing is clear and unambiguous* – *no spelling or grammatical errors*	**Feedback**

Appendix 2.8C:
Microthemes—Final Draft Assessment (BLM)

Name ______________________________ Microtheme ___________________________

Science Content ❑ Accurate ❑ Complete/sufficient detail provided ❑ Uses appropriate scientific vocabulary ❑ Uses appropriate examples and/or diagrams — *detail should reflect high-school level* — *use of biological terms enhances the writing (correct use of terms, doesn't detract from flow)*	**Possible Points** 5 — met all criteria 3–4 — met most criteria 1–2 — met few criteria Score _____________	**Comments**
Task Completion ❑ Task completed effectively (e.g., explanation given, question answered, argument made, point of view represented) — *last paragraph should provide a concise summary of problem and solution, statement of recommendation, etc.* **Provide additional criteria related to specific microtheme:** ❑ ❑ ❑	**Possible Points** 5 — met all criteria 3–4 — met most criteria 1–2 — met few criteria Score _____________	**Comments**
Communication ❑ Communicates effectively (spelling, grammar, flow) ❑ Format or voice appropriate to the task or audience — *clear sentence structure* — *writing is clear and unambiguous* — *no spelling or grammatical errors*	**Possible Points** 5 — met all criteria 3–4 — met most criteria 1–2 — met few criteria Score _____________	**Comments**
	Overall Score _____________	

Appendix 2.9: Gene Technology Microtheme Assignment (BLM)

The Guy Paul Morin criminal case is a famous Canadian example of how DNA evidence freed an innocent man from life imprisonment for murder. Research the case and the use of DNA fingerprinting or profiling. Include one article on the Morin case and one article on the DNA fingerprinting procedure. Highlight the key points.

When you have done your reading, prepare to write your microtheme assignment. Imagine that the defence attorney in the 1995 trial wants to use DNA fingerprinting evidence to prove Morin's innocence. His problem is that the jury is not very familiar with the DNA fingerprinting procedure. You have been called as an expert witness for the defence, as it is felt that your explanation would be more easily understood by the jury. The defence attorney does not want a technical expert who will talk above the heads of the jury.

Prepare your presentation and write it up as a dialogue between you and the defence attorney. Be sure to outline the DNA fingerprinting procedure. As mishandling of the evidence has been a problem in this case, you must indicate how the materials were properly collected and tested. What are the proper guidelines to follow? Include one diagram that you will use to instruct the jury.

The microtheme should be 300 to 400 words in length and a dialogue format should be used. Spelling and grammar will be checked.

Part 2: Biodiversity

Unit 3: Evolutionary Theory and Biodiversity

Unit 3: Evolutionary Theory and Biodiversity

Specific Learning Outcomes

B12-3-01: Define the term *evolution*, explaining how evolution has led to biodiversity by altering populations and not individuals. (GLOs: D1, E3)

Include: gene pool and genome

B12-3-02: Describe and explain the process of discovery that led Charles Darwin to formulate his theory of evolution by natural selection. (GLOs: A2, A4, B1, B2)

Include: the voyage of the *Beagle*, Darwin's observations of South American fossils, the impact of the Galapagos Islands on his thinking, and the work of other scientists

B12-3-03: Outline the main points of Darwin's theory of evolution by natural selection. (GLO: D1)

Include: overproduction, competition, variation, adaptation, natural selection, and speciation

B12-3-04: Demonstrate, through examples, what the term *fittest* means in the phrase "survival of the fittest." (GLO: D1)

Examples: stick insects blending with their environment, sunflowers bending toward sunlight, antibiotic-resistant bacteria . . .

B12-3-05: Explain how natural selection leads to changes in populations. (GLOs: D1, E3)

Examples: industrial melanism, antibiotic-resistant bacteria, pesticide-resistant insects . . .

B12-3-06: Describe how disruptive, stabilizing, and directional natural selection act on variation. (GLOs: D1, E3)

B12-3-07: Distinguish between natural selection and artificial selection. (GLOs: D1, E1, E3)

B12-3-08: Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. (GLOs: D1, E3)

Include: large population, random mating, no gene flow, no mutation, and no natural selection

B12-3-09: Discuss how genetic variation in a gene pool can be altered. (GLOs: D1, E1, E3)

Examples: natural selection, gene flow, genetic drift, non-random mating, mutation . . .

B12-3-10: Describe how populations can become reproductively isolated. (GLOs: D1, E2)

Examples: geographic isolation, niche differentiation, altered behaviour, altered physiology . . .

B12-3-11: With the use of examples, differentiate between convergent evolution and divergent evolution (adaptive radiation). (GLOs: D1, E1)

B12-3-12: Distinguish between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. (GLOs: D1, E3)

DEFINING EVOLUTION

SPECIFIC LEARNING OUTCOME

B12-3-01: Define the term *evolution*, explaining how evolution has led to biodiversity by altering populations and not individuals. (GLOs: D1, E3)
Include: gene pool and genome

SLO: B12-3-01

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

Students will be familiar with the term *evolution*, but have not previously studied the topic.

TEACHER NOTE

Evolution is the theme that unifies all the different fields of biology. Emphasize to students the links among evolution, biodiversity, DNA, and genetics. Today, the modern synthesis combines Charles Darwin's theory of evolution by natural selection with Mendelian genetics and the findings of population biology. In genetic terms, *evolution* occurs not to individuals, but to populations, and is defined as a change in the allele frequency in a population's gene pool. The fact that evolution occurs in populations (not individuals) must be emphasized.

BACKGROUND INFORMATION

For more information about the nature of science and evolution, refer to Appendix 3.1: Nature of Science—Evolution (Teacher Background).

ACTIVATE

Evolution Survey

Survey students about their prior knowledge of evolution to determine their level of understanding, so that misconceptions can be addressed. Refer to Appendix 3.2A: Evolution Survey (BLM) and Appendix 3.2B: Evolution Survey (Teacher Background).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

ACQUIRE/APPLY

Evolution of a Style/Product—Demonstration (U1)

Use pictures or photographs to illustrate the evolution of a style or a product (e.g., hairstyles, clothing, automobiles, telephones).

Pose the following questions:

- Can you explain how the style or product is the same? (It still has the same function.)
- Can you explain how it changed over time? (Answers will vary, depending on the example used.)
- What might have caused the observed changes? (Answers will vary, depending on the example used. Answers may include improved technology, fashion design trends, and so on).
- Organisms also change over time. How is the evolution of organisms different from the evolution of styles or products? (The evolution of organisms is usually much slower.)

Defining Evolution (U2, I1, G1)

Group students into teams and have the teams consult a variety of sources to gather definitions of the term *evolution*. These sources should include print (e.g., textbook, dictionary), electronic (e.g., Internet), and personal resources (e.g., teacher, parent).

Share a biological definition of evolution with the class. Ask the groups to examine the definitions they have gathered, and compare them to the biological definition of evolution, discussing commonalities and differences. Remind students of the distinction between the reality that evolution has occurred (the fact) and the explanation for how evolution occurs (the theory of natural selection).

DEFINING EVOLUTION

SPECIFIC LEARNING OUTCOME

B12-3-01: Define the term *evolution*, explaining how evolution has led to biodiversity by altering populations and not individuals. (GLOs: D1, E3)

Include: gene pool and genome

Suggestion for Assessment

During the last five minutes of the class, have students complete an Exit Slip, reflecting on questions such as the following:

- What do you know now that you didn't know before class today?
- What did you already know?
- What questions do you still have?

Review students' responses, looking for areas of confusion, and address the questions during the next class (formative assessment). For information on Exit Slips, see *SYSTH* (p. 13.9).

What Is Evolution? (U1)

Provide students with a definition of the term *evolution*. Make the distinction between the fact that evolution has occurred (e.g., fossil evidence, DNA analysis) and the explanation for the mechanism of how evolution occurs (the theory of natural selection). Discuss that evolution occurs not to individuals, but to populations. Evolution is a change in the allele frequency in a population's gene pool.

Resource Links

- Evolution and the Nature of Science Institutes. *ENSIweb*. <www.indiana.edu/~ensiweb/>.
  This website offers a collection of lessons, interactive learning activities, and resources for teaching about the nature of science and evolution.

- The National Science Digital Library (NSDL). Home Page. <http://ndsl.org>.
  The online collections of evolution resources for teachers on this website include lesson plans, videos, interactives, and articles.

- University of California Museum of Paleontology. Home Page. <www.ucmp.berkeley.edu/>.
  This website provides links to online exhibits and educational resources on a range of topics related to evolution, including lessons, articles, modules, and interactives.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

Suggestion for Assessment

At the end of the lesson, pose the following question to students:

- How has your understanding of the term *evolution* changed?

Give students five minutes to respond in their notebooks.

The use of this quick formative assessment tool helps teachers gain information about what students learned in a particular lesson. Responses should indicate students have gained a clearer understanding of the biological definition of *evolution*.

Building Vocabulary (U1)

Introduce new vocabulary to students as required. The use of a variety of strategies (e.g., Word Cycle, Three-Point Approach) can aid students in developing both conceptual and contextual knowledge of the vocabulary of biology. For more information on building a scientific vocabulary and for examples of think-sheet frames, refer to *SYSTH* (Chapter 10).

Suggestion for Assessment

Completed think-sheet frames can be peer assessed or handed in for teacher feedback. As this learning activity is intended as a formative assessment to check student understanding, no mark is required. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

The Historical Context

SPECIFIC LEARNING OUTCOME

B12-3-02: Describe and explain the process of discovery that led Charles Darwin to formulate his theory of evolution by natural selection. (GLOs: A2, A4, B1, B2)

Include: the voyage of the *Beagle*, Darwin's observations of South American fossils, the impact of the Galapagos Islands on his thinking, and the work of other scientists

SLO: B12-3-02

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

Students have not previously studied this topic, but they may be somewhat familiar with Charles Darwin, evolution, and the concept of "survival of the fittest."

TEACHER NOTE

This learning outcome provides an opportunity to explore the nature of science with students. For example, while Jean Baptiste Lamarck's ideas may seem silly to us today, in his time, he was a well-respected scientist who was one of the first to propose a mechanism explaining how organisms change over time. The fact that his theory was discarded when another theory with a better explanation was proposed is an excellent illustration of how science works.

BACKGROUND INFORMATION

The dynamic nature of the "evolution" of evolution is a vehicle with which to explore the nature of science with students. Contributing scientists include the following:

- **James Hutton** (1726–1797) and **Charles Lyell** (1797–1875) studied the forces of wind, water, earthquakes, and volcanoes. They concluded that the Earth is very old and has changed slowly over time due to natural processes.
- **Erasmus Darwin** (1731–1802) suggested that competition between individuals could lead to changes in species. (He was Charles Darwin's grandfather.)
- **Jean Baptiste Lamarck** (1744–1829) proposed a mechanism by which organisms change over time. He hypothesized that living things evolve through the inheritance of acquired characteristics.
- **Thomas Malthus** (1766–1834) observed that human populations cannot keep growing indefinitely. If the human birth rate continued to exceed the death rate, eventually humans would run out of living space and food. According to Malthus, famine, disease, and war prevented endless population growth.
- **Charles Darwin** (1809–1882) formulated a theory of evolution by natural selection based on observations made during his voyage on the *Beagle*, and of selective breeding of farm animals, plants, and pets. Darwin drafted manuscripts outlining his theory in the 1840s but hesitated to release them to the public. His most famous work *On the Origin of Species by Means of Natural Selection* was published in 1859.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

- **Alfred Russell Wallace** (1823–1913) proposed a theory of evolution by natural selection similar to that of Darwin's theory. He wrote a paper and sent it to Darwin to review. This spurred Darwin on to agree, finally, to the release of his theory. In 1858, Charles Lyell presented Darwin's 1844 essay and Wallace's paper to the public.

ACTIVATE

Setting the Scene—Think-Pair-Share

Pose the following scenario to students:

Imagine that you are 21 years old and have just graduated from university. You aren't quite sure whether you want to settle down and start working in your field of study. You have always enjoyed going on hikes and observing nature. One day you see a job advertisement in the paper. The government is looking for people to work on a five-year surveying expedition around the coast of South America. Would you apply for the job? Why or why not?

Provide students with time to think about and formulate responses to the scenario individually. Students then pair up with a partner to discuss whether they would apply for the job and give reasons for their decisions.

ACQUIRE/APPLY

The Story of Charles Darwin—Article Analysis (U1, N2)

The story of Charles Darwin is a fascinating one. For a brief summary of his life and work, see Appendix 3.3: The Story of Charles Darwin (BLM). Ask students to read the article and complete a Fact-Based Article Analysis Frame (see *SYSTH*, pp. 11.30–11.31, 11.41).

THE HISTORICAL CONTEXT

SPECIFIC LEARNING OUTCOME

B12-3-02: Describe and explain the process of discovery that led Charles Darwin to formulate his theory of evolution by natural selection. (GLOs: A2, A4, B1, B2)

Include: the voyage of the *Beagle*, Darwin's observations of South American fossils, the impact of the Galapagos Islands on his thinking, and the work of other scientists

Encourage students to use effective reading strategies to acquire new knowledge from text. This includes activating their prior knowledge before the reading, taking some form of notes during the reading, and discussing/reflecting on what they read. For more information about strategies for reading scientific information, refer to *SYSTH* (Chapter 12).

Suggestion for Assessment

Scan the completed Fact-Based Article Analysis Frames to assess students' understanding. The information gathered can be used to plan further instruction.

Darwin's Process of Discovery (U1)

Use a variety of visuals and multimedia to explain the process of discovery that led Darwin to formulate his theory of evolution by means of natural selection.

The use of a note-taking strategy such as a Note Frame can help students follow a lecture and organize information. For more information, refer to *SYSTH* (p. 11.32).

Resource Links

- The Complete Work of Charles Darwin Online. Home Page. <www.darwin-online.org.uk/>.

  This website contains Darwin's publications, private papers, illustrations, field notebooks, and letters.

- PBS Online. *Evolution*. <www.pbs.org/wgbh/evolution/>.

  The eight-part PBS television series *Evolution* (aired September 2001) addresses a variety of topics related to evolution (including Charles Darwin), extinction, and survival. The series website contains resources for learning about and teaching evolution, an extensive library of print and multimedia resources, web activities, and animations.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

Suggestion for Assessment

Note Frames can serve as a useful tool for teachers to monitor students' understanding (formative assessment) and to adjust teaching to address any difficulties. Students can also compare their Note Frames and provide each other with feedback (peer assessment). For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

Evolution Timeline—Research and Presentation (U2, I1, I4, N1)

Have students (individually or in small groups) research a scientist who contributed to the development of a unifying theory explaining how species can change over time.

Students research their assigned scientist and create a poster summarizing the following:

- date of work or publication
- key finding(s)/contribution(s)
- contextual information (e.g., where and when the scientist worked, biographical information on the scientist)

The posters can then be used to create a timeline/flow chart illustrating the development of evolutionary theory. The timeline/flow chart could be displayed in the classroom.

THE HISTORICAL CONTEXT

SPECIFIC LEARNING OUTCOME

B12-3-02: Describe and explain the process of discovery that led Charles Darwin to formulate his theory of evolution by natural selection. (GLOs: A2, A4, B1, B2)

Include: the voyage of the *Beagle*, Darwin's observations of South American fossils, the impact of the Galapagos Islands on his thinking, and the work of other scientists

Resource Link

- The University of California Museum of Paleontology. *Understanding Evolution*. <http://evolution.berkeley.edu/>.

  This website hosts a variety of online exhibits. See "What Is the History of Evolutionary Theories?" in the *Resource Library* for the history of ideas, research, and contributors in the study of evolution.

Suggestions for Assessment

Students prepare and present their research findings and posters to the class.

Create an assessment rubric for the presentations/posters by developing the assessment criteria and performance levels in collaboration with students. The assessment criteria could include

- content
- organization
- visuals

Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. Also refer to Appendix 5.8: Checklist for Creating Visuals (BLM).

Postcards from the *Beagle*—Creative Writing Assignment (U2, I1, I4, N1)

RAFTs are creative writing assignments in which students are encouraged to adopt new perspectives on a science concept or issue. For more information, see *SYSTH* (pp. 13.22–13.25). In this learning activity, students assume the persona of Charles Darwin and send home postcards describing their thoughts and observations during the voyage on the HMS *Beagle* (1831–1836). For assignment details, refer to Appendix 3.4: Postcards from the *Beagle*—Creative Writing Assignment (BLM).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

Suggestions for Assessment

Create an assessment rubric for the writing assignment by developing the assessment criteria and performance levels in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. Criteria could include biology content, word choice, mechanics, and so on. Alternatively, provide students with strong and weak exemplars of postcards, and have them work in groups to identify possible assessment criteria and define levels of performance. The exemplars can be teacher-generated or anonymous samples of student work done in previous years.

DARWIN'S THEORY

SPECIFIC LEARNING OUTCOME

B12-3-03: Outline the main points of Darwin's theory of evolution by natural selection. (GLO: D1)

Include: overproduction, competition, variation, adaptation, natural selection, and speciation

SLO: B12-3-03

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Emphasize that variation in a species is the result of mutations in DNA. These mutations are the source of new alleles, the variations upon which natural selection can act. It is important to remind students that mutations are not goal-directed. They arise randomly in a population, and may produce a change in the structure or function of the organism. Whether the mutation is beneficial or harmful depends on the environment. Evolution then selects for those organisms that are best adapted to their environment at the time.

ACTIVATE

Opening Questions

Pose the following questions to students. Ask them to work in teams to generate responses and have them record their responses in their notebooks.

- Some forms of bacteria can divide by fission as frequently as every 20 minutes in optimal conditions. Assuming we start with one bacterium, how many bacteria could be produced
  - after one minute? (8)
  - after two minutes? (64)
  - after five minutes? (37,268)
  - after 30 minutes? (1.07×10^9)

Then ask the following question:

- So why aren't we drowning in bacteria?

Possible responses could include the following:

- The bacteria could run out of food.
- The bacteria could run out of oxygen.
- The bacteria could run out of living space.
- Some bacteria could die of old age.
- Some bacteria could be eaten by predators (e.g., white blood cells, mosquito larvae).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

ACQUIRE/APPLY

Darwin's Theory—Class Discussion (U1)

Engage students in a discussion of their responses to the Opening Questions as an introduction to the main points of Darwin's theory of evolution by natural selection. The main points are summarized below:

- **Overproduction:** More offspring are produced by an organism than can possibly survive.
- **Competition:** High birth rates cause a shortage of life's necessities, leading to competition between organisms.
- **Variation:** Each individual differs from all other members of its species; some differ more than others.
- **Adaptation:** Variations help some organisms to be better suited to their environments than others.
- **Natural selection:** The most fit (best adapted) organisms survive and reproduce.
- **Speciation:** New species form from ancestral species by means of natural selection.

The use of the Three-Point Approach can aid students in developing their understanding of the terminology. For more information about this strategy, refer to *SYSTH* (pp. 10.9–10.10).

Suggestion for Assessment

Students can submit their completed work for teacher feedback. As this learning activity is intended as a formative assessment to check student understanding, no mark is required.

DARWIN'S THEORY

SPECIFIC LEARNING OUTCOME

B12-3-03: Outline the main points of Darwin's theory of evolution by natural selection. (GLO: D1)

Include: overproduction, competition, variation, adaptation, natural selection, and speciation

What Darwin Said (U1)

Use videos and computer animations that illustrate and describe the main points of Darwin's theory to enhance students' conceptual understanding. A wealth of information can be found in a variety of multimedia formats.

Resource Link

- PBS Online. "Evolution." *NOVA beta.* <www.pbs.org/wgbh/nova/beta/evolution/>.

  This website has online *NOVA* television episodes, interactives, and the latest news in evolution science, as well as links to other evolution-related websites and resources.

Suggestion for Assessment

At the end of the lesson, distribute index cards or half sheets of paper. Ask students to describe the "muddiest point" of the lesson—that is, the ideas or parts of the lesson that were confusing or difficult to understand (Gregory, Cameron, and Davies). Let students know you will be using the information to plan the next lesson to benefit them best. At the start of the next lesson, share with students examples of responses that informed your instructional decisions. This will help them realize that you are taking their responses seriously, and they will respond thoughtfully and with more detail in the future.

Simulating Natural Selection—Laboratory Investigation (U2, S2, S3, S5, I4)

Students investigate natural selection by using different utensils to "capture food." For details, see Appendix 3.5A: Natural Selection Simulation (BLM) and Appendix 3.5B: Natural Selection Simulation (Teacher Background).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Suggestion for Assessment

Assessment of this investigation can be summative (written responses to the questions posed) or formative. The RERUN strategy (Keeley 172–73) can be used for formative assessment of student learning in place of a formal summative lab report.

After students have completed the investigation and answered questions about it, ask them to reflect on their lab experience (individually or in groups) by writing a sentence or two for each letter of the acronym, **RERUN**: **R**ecall (what you did), **E**xplain (why you did it), **R**esults (what you found out), **U**ncertainties (what remains unclear), and **N**ew (what you learned).

ADAPTATION

SPECIFIC LEARNING OUTCOME

B12-3-04: Demonstrate, through examples, what the term *fittest* means in the phrase "survival of the fittest." (GLO: D1)

Examples: stick insects blending with their environment, sunflowers bending toward sunlight, antibiotic-resistant bacteria . . .

SLO: B12-3-04

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Adaptation is the result of natural selection. Species that are well adapted to their environments tend to be successful. They survive and reproduce, but again they are not perfect. Should the environment change, many will die, as they are no longer suited to the new environment.

Make a clear distinction between adaptation and acclimatization. *Acclimatization* occurs when an organism becomes accustomed to changing environmental conditions. It is not the product of natural selection. There is no change in the gene pool of the species. For example, when warm spring weather arrives after the cold of winter, we are quick to shed our winter coats and put on shorts and sandals, even though the temperature may be only 10°C. However, should a cold front sweep down from the north in the middle of summer and the temperature fall to 15°C, we would put on jackets and complain about how cold it is. We are acclimatized to the warmer temperatures of summer.

ACTIVATE

Survival of the Fittest—Class Discussion

Provide students with visuals (e.g., overheads, PowerPoint presentations, diagrams, pictures) of organisms with structural, behavioural, or physiological adaptations (e.g., needles on a cactus, canine teeth on a carnivore such as a wolf, seasonal feather colour change in ptarmigans).

Ask students to describe ways in which each organism is well suited to its environment. What special feature does each have that increases its chance of survival or reproduction? What makes the organism fit?

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

ACQUIRE/APPLY

What Is an Adaptation? (U1)

With the use of examples, distinguish among behavioural, structural, and physiological adaptations. In the discussion of structural adaptations, include examples of mimicry and camouflage (also known as *cryptic colouration*). For more information about adaptation, see Appendix 3.6: Adaptation (Teacher Background).

Use note-taking strategies such as the following to provide students with processing time to enhance their conceptual understanding:

- **10 + 2 Note Taking:** Present information for 10 minutes, and then have each student summarize or discuss the material with a partner for two minutes.
- **Three-Minute Pause:** Lecture for a period of time, and then pause for three minutes to allow students to process information with a partner or a small group.

Suggestion for Assessment

Post the following question on the classroom board so that all students can see it:

- What is an adaptation?

In addition, write the question at the top of a piece of paper and pass it around the class during instruction so that it moves from student to student. Each student must add one or two sentences that relate to the question, and build upon or correct previous student comments.

At the end of the lesson, examine the response chain to assess students' comprehension, and re-teach material if necessary (formative assessment).

Adaptation

Specific Learning Outcome

B12-3-04: Demonstrate, through examples, what the term *fittest* means in the phrase "survival of the fittest." (GLO: D1)

Examples: stick insects blending with their environment, sunflowers bending toward sunlight, antibiotic-resistant bacteria . . .

Adaptation—Concept Frame (U2)

Graphic organizers assist students in clarifying their thinking and enhance their learning. Have students complete a Concept Frame for the concept of adaptation. Refer to Appendix 1.16: Concept Frame.

Suggestion for Assessment

Assess students' Concept Frames for conceptual understanding and provide descriptive feedback on how they could be improved.

Survival of the Fittest—Demonstrating Understanding (U2)

Pose the following question to students at the end of the lesson:

- With the use of an example, explain what the term *fittest* means in the phrase "survival of the fittest."

Give students five minutes to respond in their notebooks.

Suggestion for Assessment

This learning activity provides a quick formative assessment of what students learned in the lesson. Students' responses should include the following:

- The explanation of the term *fittest* incorporates the use of an example.
- Organisms that are better adapted to their environment are more fit, thereby increasing their chance of survival and successful reproduction.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Adaptation Poster—Research and Presentation (U2, P1, I1, I4)

Students individually research an adaptation in a species of their choice, and present their findings in the form of a poster. The poster should include the following components:

- the name of the species
- a description of the adaptation
- the type of adaptation present (behavioural, physiological, structural)
- an explanation of how the adaptation allows an organism to be better suited to its environment
- a picture, drawing, or diagram of the organism

Suggestions for Assessment

Refer to Appendix 5.8: Checklist for Creating Visuals (BLM) for use with visuals such as posters, collages, graphic organizers, and so on.

Provide students with exemplars of strong and ineffective posters, and have them work in groups to identify possible assessment criteria and define levels of performance for a rubric. The exemplars can be teacher-generated or anonymous samples of student work done in previous years.

Alternatively, assessment criteria can be constructed in collaboration with the class by brainstorming components of the rubric. The criteria could include

- content
- organization
- visuals

Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process.

NATURAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-05: Explain how natural selection leads to changes in populations. (GLOs: D1, E3)

Examples: industrial melanism, antibiotic-resistant bacteria, pesticide-resistant insects . . .

SLO: B12-3-05

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Caution students against assuming that natural selection and evolution lead to perfection in organisms. Natural selection operates on the variation already present in a species; it cannot create new structures or processes. Regardless of how much time humans spend in the sunlight, for example, we will never be able to manufacture our own food through photosynthesis.

BACKGROUND INFORMATION

Microevolution is the term used to describe changes that occur within a population of a single species. It includes the process of natural selection, changes in allele frequencies, and changes in populations that result over time. Industrial melanism and development of antibiotic-resistant bacteria are examples of microevolution.

Macroevolution refers to large-scale and long-term evolutionary patterns among many species. The evolution of new species from a common ancestor, as seen in Hawaiian honeycreepers and Darwin's finches, or the origin, adaptive radiation, and extinction of the dinosaurs are examples of macroevolution. Evolutionary biologists today are debating the extent to which microevolutionary mechanisms can explain macroevolutionary patterns (Martin, *Missing Links*).

ACTIVATE

Natural Selection in a Candy Dish—Demonstration

In this learning activity, students become unwitting subjects in a demonstration about natural selection. Students select candies from a bowl and have the opportunity to think about what brought about the "survival" of some candies. See Appendix 3.7: Natural Selection in a Candy Dish (Teacher Background).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

ACQUIRE/APPLY

Natural Selection in Legocarnivora—Investigation (U2, S3, S4, S5)

This learning activity simulates natural selection with fictitious animals constructed of Lego® blocks. See Appendix 3.8A: Natural Selection in Legocarnivora (BLM) for the investigation. Also see Appendix 3.8B: Natural Selection in Legocarnivora (Answer Key).

Suggestion for Assessment

Specify in advance the criteria for assessment of the investigation. Lab skills and group work skills can be assessed using a checklist. Refer to Appendix 1.3: Student Lab Skills (Teacher Background), Appendix 1.4A: Lab Skills Checklist—General Skills (BLM), Appendix 1.4B: Lab Skills Checklist—Thinking Skills (BLM), and Appendix 1.13: Collaborative Process—Assessment (BLM).

NATURAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-05: Explain how natural selection leads to changes in populations. (GLOs: D1, E3)

Examples: industrial melanism, antibiotic-resistant bacteria, pesticide-resistant insects . . .

I'm Looking over a White-Striped Clover: A Case for Natural Selection—Case Study/Culminating Task (U2, S1, S5, I1)

A case study can be used as a culminating task for the unit, bringing together a number of knowledge and skills and attitudes outcomes.

The case study "I'm Looking over a White-Striped Clover" by Susan Evarts, Alison Krufka, and Chester Wilson (available on the National Center for Case Study Teaching in Science website) explores the process of natural selection. Regardless of whether students work on the case study individually or in small groups, encourage them to use effective reading strategies to acquire new knowledge and information from the text. This includes activating their prior knowledge before reading the case study, taking some form of notes while reading, and having an opportunity to discuss and/or reflect on what they read in the case study.

Resource Links

- Evarts, Susan, Alison Krufka, and Chester Wilson. "I'm Looking over a White-Striped Clover: A Case of Natural Selection." 28 Nov. 2006. *Case Collection.* National Center for Case Study Teaching in Science. <http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=272&id=272>. Case Teaching Notes are available at <http://sciencecases.lib.buffalo.edu/cs/files/clover_notes.pdf>.

- National Center for Case Study Teaching in Science, University at Buffalo. Home Page. <http://sciencecases.lib.buffalo.edu/cs/>.

  This website provides access to a variety of case studies, which teachers can modify or adapt for classroom use, subject to the specified usage guidelines. Teaching notes and answer keys for the case studies are available free of charge. To access the answer keys, users are required to register for a password.

Suggestion for Assessment

Whatever the form of assessment used, students should be made aware of the criteria beforehand. Assessment criteria can be developed in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

Understanding Natural Selection (U1, N1, N3)

The use of examples will enhance students' understanding of how natural selection leads to changes in populations. There are many cases in which natural selection has been observed in action, including H. B. Kettlewell's study of camouflage adaptation in a population of light-coloured and dark-coloured pepper moths in England, and the development of antibiotic-resistant bacteria ("superbugs") such as *Staphylococcus aureus.*

Suggestion for Assessment

The use of Note Frames assists teachers in monitoring students' understanding (formative assessment). The information gained from Note Frames can be used to adjust teaching to address difficulties. Students can also compare their Note Frames and provide each other with feedback (peer assessment). For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

NATURAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-05: Explain how natural selection leads to changes in populations. (GLOs: D1, E3)

Examples: industrial melanism, antibiotic-resistant bacteria, pesticide-resistant insects . . .

I'm Feeling Better, So Why Do I Need to Finish This Prescription?—Microtheme (U2, S1, D4, I1, I2, I4)

Microthemes are short writing assignments designed to help students learn the material by looking at it in a different way (Martin). They require more than simply reading the text or articles and memorizing notes. A specific problem is addressed in each microtheme, allowing the writer to illustrate his or her understanding. Refer to Appendix 2.8A: Microthemes (Teacher Background) for more information on microthemes.

Provide students with the following scenario:

> *Your friend was recently diagnosed with strep throat, an infection that causes a sore throat and fever. Her doctor said the infection is easily treated and cured and gave her a prescription for an antibiotic. When you accompanied your friend to the pharmacist to get the prescription filled, the pharmacist told her to finish all the antibiotic pills, and not discontinue taking it, even if she started to feel better.*
>
> *After taking the antibiotic pills for three days, your friend started to feel better. She is thinking about not finishing the treatment. Explain to your friend why it is important that she finish the entire antibiotic treatment. Refer to variation and natural selection in your explanation.*

Suggestion for Assessment

Discuss assessment criteria for the microtheme with the class. Refer to Appendix 2.8B: Microthemes—First Draft Checklist (BLM) and Appendix 2.8C: Microthemes—Final Draft Assessment (BLM).

In their responses, students should discuss the development of antibiotic-resistant bacteria as an example of natural selection in action. Variation in antibiotic resistance occurs naturally within a bacterial population. Some bacteria have a low resistance and are killed rapidly when the antibiotic is present. However, some bacteria do survive and reproduce, as they are better adapted to their environment (i.e., more fit). To kill the more resistant bacteria, the entire course of antibiotic treatment must be completed.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

If treatment stops before all the bacteria are killed, the resistant bacteria will survive and reproduce. With less competition from other bacteria, the resistant bacteria population quickly increases. The person will likely become sick with the same illness again. The antibiotic that had once controlled the bacteria is no longer effective. The person may require longer treatment with the same antibiotic or may require a different antibiotic for treatment.

EFFECTS OF NATURAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-06: Describe how disruptive, stabilizing, and directional natural selection act on variation. (GLOs: D1, E3)

SLO: B12-3-06

SUGGESTIONS FOR INSTRUCTION

ACTIVATE

Bell-Shaped Curve—Demonstration

Working in pairs, students measure their heights and round off the measurements to the nearest 0.05 metres (e.g., 1.60 m, 1.85 m). As a large group, determine the maximum and minimum heights of students in the class. Draw a continuum across the whiteboard, with the minimum and maximum heights at opposite ends. In between these heights, note the intermediate heights on the board. Ask students to stand in front of the board at their height. Should there be more than one student per height, ask the students to form a row in front of the height. When the students are organized, a bell-shaped curve will likely result. This reflects the height variation of students in the classroom.

ACQUIRE/APPLY

The Effects of Selection on Variation (U1)

With the use of graphs and examples, illustrate the effects of stabilizing, directional, and disruptive selection on the variation in a population. Refer to Appendix 3:9: Effects of Selection on Variation (Teacher Background) for more information.

Use note-taking strategies such as the following to provide students with processing time to enhance their conceptual understanding:

- **10 + 2 Note Taking:** Present information for 10 minutes, and then have each student summarize or discuss the material with a partner for two minutes.
- **Three-Minute Pause:** Lecture for a period of time, and then pause for three minutes to allow students to process information with a partner or a small group.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Suggestion for Assessment

During the last five minutes of the class, have students complete an Exit Slip, reflecting on questions such as the following:

- What do you know now that you didn't know before class today?
- What did you already know?
- What questions do you still have?

Review students' responses, looking for areas of confusion, and address the questions during the next class (formative assessment). For information on Exit Slips, see *SYSTH* (p. 13.9).

Three-Point Approach (U2)

Graphic organizers enhance students' learning, as they assist students in clarifying their thinking. Have students complete a Three-Point Approach frame for the following terms: *stabilizing*, *directional*, and *disruptive selection*. For more information on the Three-Point Approach, refer to *SYSTH* (pp. 10.9–10.10, 10.22).

Suggestion for Assessment

Assess students' Three-Point Approach frames for conceptual understanding, and, if necessary, adjust instruction to address students' misconceptions.

EFFECTS OF NATURAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-06: Describe how disruptive, stabilizing, and directional natural selection act on variation. (GLOs: D1, E3)

Investigating Variation—Investigation (U2, P1, S3, S4, S5, I4)

In this learning activity, students examine observable differences in a trait. Students measure the length of dried beans (e.g., kidney, lima, pinto) and graph the class results. For details on this investigation, refer to Appendix 3.10A: Investigating Variation (BLM) and Appendix 3:10B: Investigating Variation (Answer Key).

Suggestions for Assessment

Specify in advance the criteria for assessment of the investigation. For information on the process of developing assessment criteria in collaboration with students, refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background). Lab skills and group work skills can be assessed using a checklist. Refer to Appendix 1.3: Student Lab Skills (Teacher Background), Appendix 1.4A: Lab Skills Checklist—General Skills (BLM), Appendix 1.4B: Lab Skills Checklist—Thinking Skills (BLM), and Appendix 1.13: Collaborative Process—Assessment (BLM).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

NOTES

ARTIFICIAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-07: Distinguish between natural selection and artificial selection. (GLOs: D1, E1, E3)

SLO: B12-3-07

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Students will be familiar with artificial selection with respect to various breeds of dogs and cats. Some may be familiar with varieties of fruits and vegetables or varieties of domestic farm animals (e.g., horses, cattle, chickens).

BACKGROUND INFORMATION

Both natural selection and artificial selection are mechanisms of change in the gene pool of a population. The key difference is that in artificial selection, humans ensure that individuals with the more desirable traits are allowed to reproduce. In natural selection, those individuals who are best suited to their environment survive and reproduce.

Artificial selection is a form of non-random mating, one of the causes of change to a gene pool. For centuries, breeders have used the natural variation within a population to breed selectively those plants or animals that best represent the properties they wish for in future generations, such as more productive milk cows, earlier ripening fruits, greater grain yields, and faster racehorses. Charles Darwin was able to use artificial selection as a model for change in the natural world (i.e., natural selection).

ACTIVATE

What Makes a Squash, a Squash?—Demonstration

Provide students with samples of different types of winter squash such as acorn, butternut, Hubbard, pumpkin, and spaghetti squash. All are members of the same species, *Curcurbita maxima*. Ask students to write an explanation of how they think humans were able to produce such a variety of squash.

Alternatively, the many varieties of *Brassica oleracea* (e.g., broccoli, broccoflower, cauliflower, cabbage, Brussels sprouts, kale, kohlrabi, collard greens, Chinese broccoli, rapini) could be used in this demonstration. All these varieties are derived from wild mustard through artificial selection.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

ACQUIRE/APPLY

Guest Speaker (U2, P2, I1)

Invite a local plant or animal breeder to the class. Have students prepare questions for the speaker in advance of the visit.

Questions could include the following:

- What type of plant/animal do you breed?
- What are the traits for which your plant/animal is bred?
- What selective breeding practices do you use for your animals? How do you propagate your plants?

This is also a good opportunity for students to explore related careers.

Suggestion for Assessment

Students summarize the highlights of the guest speaker's presentation in their notebooks. Summaries can be shared with classmates and peer assessed for content. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

ARTIFICIAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-07: Distinguish between natural selection and artificial selection. (GLOs: D1, E1, E3)

Artificial Selection—Field Trip (U2, P2, I1)

Visit a plant research station, a local horticulturalist, or an animal breeder for a demonstration of traits selected for in a plant or an animal and the selective breeding practices used. This is a good opportunity for students to explore related careers.

Suggestion for Assessment

Have students complete an I Used to Think, But Now I Know reflection after the field trip. Ask students to recall their ideas at the start of the topic discussion, and explain how their ideas changed or became more detailed compared to what they knew at the beginning of instruction (Keeley). Students can discuss their reflections with a partner.

Breed of Organism—Research and Presentation (U2, I1, I2, 14)

Students individually select and research a breed/varietal/cultivar of organism (e.g., Siamese cat, Hereford cattle, hybrid tea rose, cocker spaniel, hard red spring wheat). In their report findings, students should include the following:

- the name of the breed/varietal/cultivar
- the characteristics or traits selected for
- a picture of a representative organism

Suggestions for Assessment

Students prepare and present their research reports. Research findings can be presented in a variety of formats:

- multimedia presentation (e.g., PowerPoint, video, wiki)
- written report
- visual display (poster, bulletin board)

Develop assessment criteria for the report and presentation in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. The criteria should include both content and presentation components. The content criteria should include use of key terms and understandings from the unit. Presentation components will vary, depending on the type of presentation (oral or written).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Where Did All the Four-Leaf Clovers Go?—Case Study (U2, S1, S5)

Have students answer questions in response to the case study presented in Appendix 3.11A: Where Did All the Four-Leaf Clovers Go?—Case Study (BLM). Also see Appendix 3.11B: Where Did All the Four-Leaf Clovers Go?—Case Study (Answer Key).

Suggestion for Assessment

Completed case studies can be handed in for teacher feedback. The feedback provided should be specific and descriptive, describing the performance rather than making a judgment or giving an opinion.

Population Genetics

SPECIFIC LEARNING OUTCOME

B12-3-08: Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. (GLOs: D1, E3)

Include: large population, random mating, no gene flow, no mutation, and no natural selection

SLO: B12-3-08

Suggestions for Instruction

Teacher Note

Prior to discussing the Hardy-Weinberg principle equation, introduce students to the conditions required to maintain genetic equilibrium. Emphasize that as it is virtually impossible to meet these conditions, allelic frequencies do change in populations and, therefore, evolution does occur.

The main application of the Hardy-Weinberg principle in population genetics is in calculating allele and genotype frequencies in a population. It is the means by which changes in gene frequency and their rate of change are determined. Students should have the opportunity to perform population genetics calculations.

Background Information

The *Hardy-Weinberg principle* is a mathematical model that deals with the frequencies of alleles in a gene pool. If the allelic frequency does not change in a population over successive generations, then evolution does not occur and the population is at equilibrium. The following conditions must be met to maintain this equilibrium:

- No mutation occurs so that the alleles do not change.
- Immigration and emigration do not occur as they would alter the gene pool.
- The population must be large so that changes do not happen by chance alone.
- All reproduction must be totally random so that one form of the allele is not selected for over another.
- All forms of the allele must reproduce equally well so that there is no natural selection.

As it is virtually impossible to meet these conditions, allelic frequencies do change in populations and, therefore, evolution does occur. The Hardy-Weinberg principle is also useful in explaining why genotypes within a population tend to remain the same, as well as for determining the frequency of a recessive allele.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

ACTIVATE

Earlobe Allele Frequencies—Demonstration

Students often wonder why recessive alleles do not disappear from a population. This demonstration can be used to illustrate the frequency of a recessive allele. Free earlobes are caused by a dominant gene (*E*), while attached earlobes are due to the homozygous recessive gene (*ee*).

1. Survey the class to determine the number of students with free earlobes and the number with attached earlobes.

   Sample data: 15 students with free and 5 with attached earlobes

2. Determine the frequency of the recessive allele using the frequency of individuals homozygous for the recessive allele (q^2).

   Sample data: 5/20 students (25% or 0.25) are *ee* (i.e., q^2). The frequency of the recessive allele is the square root of 0.25, or 0.50 (i.e., q). Remind students that all calculations are carried out using proportions, not percentages.

3. Determine the frequency of the dominant allele using $p + q = 1$.

   Sample data: The frequency of the dominant allele is, therefore, 1 – 0.50 or 0.50 (i.e., $1 - q = p$).

4. Determine the frequency of individuals homozygous for the dominant allele (p^2).

   Sample data: $(0.50)^2 = 0.25$

5. Determine the frequency of heterozygous individuals ($2pq$).

   Sample data: $2(0.50)(0.50) = 0.50$

6. Check calculations using the Hardy-Weinberg principle equation ($p^2 + 2pq + q^2 = 1$).

   Sample data: $0.25 + 2(0.50)(0.50) + 0.25 = 1$

POPULATION GENETICS

SPECIFIC LEARNING OUTCOME

B12-3-08: Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. (GLOs: D1, E3)

Include: large population, random mating, no gene flow, no mutation, and no natural selection

Discuss how this example illustrates how frequently a recessive gene may occur in a population, even though the number of homozygous recessive individuals is quite low.

ACQUIRE/APPLY

Introducing the Hardy-Weinberg Principle Equation (U1)

Introduce students to calculations of allele and genotype frequencies using the Hardy-Weinberg principle equation ($p^2 + 2pq + q^2 = 1$). This equation can be applied to populations with a simple genetic situation, with dominant and recessive alleles controlling a single trait.

In a population, the frequency alleles in a stable population will equal to 1. This can be expressed as $p + q = 1$, where

p = frequency of the dominant allele
q = frequency of the recessive allele

Use the example below to illustrate the Hardy-Weinberg principle equation ($p^2 + 2pq + q^2 = 1$), where

p^2 = frequency of individuals homozygous for the dominant allele
q^2 = frequency of individuals homozygous for the recessive allele
$2pq$ = frequency of individuals with the heterozygous genotype

The distribution of the sickle-cell anemia allele can be used as an example for calculations. In some areas of Africa, the recessive sickle-cell allele has a frequency of 0.3. The frequency of the normal hemoglobin allele is calculated as 1 – 0.3 = 0.7.

$2(0.70)(0.3) = 0.42 = Ss$ (42% of the population)
$0.3^2 = 0.09 = ss$ (9% of the population affected by sickle-cell anemia)
$0.49 + 0.42 + 0.09 = 1$

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

Based on these calculations, one can determine that although a relatively small percentage of individuals (9%) in the population are affected by sickle-cell anemia, the recessive allele is widely distributed in the population. In fact, 51% of the population carries at least one copy of the sickle-cell allele. This example can be used to illustrate why recessive alleles are not removed from a population, even though the number of individuals with the homozygous recessive condition may be quite low.

Population Genetics Calculations—Each One Teach One (U2, G2)

Provide pairs of students with a variety of problems involving Hardy-Weinberg principle equation calculations. Students work collaboratively to solve the problems and explain to their partners how they were able to determine answers to the problems (their metacognitive processes). See Appendix 3.12A: Population Genetics Calculations (BLM) and Appendix 3.12B: Population Genetics Calculations (Answer Key). The sample problems and answers provide examples of typical problems and solutions.

Suggestion for Assessment

Completed calculations can be handed in for teacher feedback. Provide feedback that is specific and descriptive, describing the performance rather than making a judgment or giving an opinion. This will help students repeat success and know what they need to improve. General comments (e.g., “Try harder next time” or “Good work”) are less effective than specific and descriptive comments (e.g., “You have correctly determined the frequency of the dominant and recessive alleles. Check your work: does $0.2^2 = 0.4$?”).

POPULATION GENETICS

SPECIFIC LEARNING OUTCOME

B12-3-08: Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. (GLOs: D1, E3)

Include: large population, random mating, no gene flow, no mutation, and no natural selection

Using the Hardy-Weinberg Principle Equation—Investigation (U2, S3, S5)

Students calculate the gene and allele frequencies of a human trait. Refer to Appendix 3.13A: Using the Hardy-Weinberg Principle Equation—Investigation (BLM) and Appendix 3.13B: Using the Hardy-Weinberg Principle Equation—Investigation (Answer Key).

Suggestion for Assessment

Assess the responses to determine students' levels of conceptual understanding and to guide further teaching and/or learning activity selection (if needed).

The Hardy-Weinberg Principle—Demonstrating Understanding (U1)

Pose the following to students:

- Some people think that the dominant allele of a gene should constantly increase in frequency in a population, and quickly force out the recessive allele. Use the Hardy-Weinberg principle and/or equation to explain why this idea is incorrect. What false assumption could cause people to have this incorrect idea?

Suggestion for Assessment

This task provides a quick formative assessment of what students learned in a particular lesson. Students' responses should include the following:

- People may assume that because few individuals show the recessive phenotype, the recessive allele is rare.
- The Hardy-Weinberg principle equation can show how widespread a recessive allele is in a population, even though few individuals show the recessive phenotype.
- Large populations are relatively genetically stable and large shifts in allele frequencies do not occur from one generation to the next.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

NOTES

MECHANISMS FOR GENETIC VARIATION

SPECIFIC LEARNING OUTCOME

B12-3-09: Discuss how genetic variation in a gene pool can be altered. (GLOs: D1, E1, E3)

Examples: natural selection, gene flow, genetic drift, non-random mating, mutation . . .

SLO: B12-3-09

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

In learning outcome B12-3-08, students are introduced to the conditions required to maintain genetic equilibrium. Students should understand that, as it is virtually impossible to meet these conditions, allelic frequencies do change in populations. Use this as a springboard for a discussion into how genetic variation in a gene pool can be altered.

BACKGROUND INFORMATION

- Natural selection affects variations in a population, as the better adapted (more fit) individuals survive and reproduce, passing on their genes to successive generations.
- Immigration and emigration of individuals from a population will affect allele frequencies and, therefore, gene flow.
- The change in the gene pool of a small population due to random chance is *genetic drift*. The bottleneck effect is a form of genetic drift that results from the near extinction of a population. The *founder* effect is a form of genetic drift that results from a small number of individuals colonizing a new area. In both cases, allele frequencies can change dramatically.
- In animals, non-random mating is often the case, as the choice of mates is often an important part of behaviour (e.g., courtship rituals). Many plants self-pollinate, which is a form of inbreeding or non-random mating.
- Mutations occur constantly. They provide the source of new alleles, or variations upon which natural selection can take place.

ACTIVATE

Thinking Like a Scientist

Ask students to recall the conditions required to maintain genetic equilibrium (see learning outcome B12-3-08 for details). Reminding students that it is virtually impossible to meet these conditions, ask students to think like scientists and work in groups to propose situations/events that may alter a gene pool. For example, the condition of no gene flow could be affected by immigration and emigration.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

Acquire/Apply

How Can Variation in a Gene Pool Be Altered? (U1)

Use the Hardy-Weinberg principle equation, in conjunction with simulations, animations, and examples, to demonstrate how the allele frequencies in a founding population can evolve differently from those of the parent population.

There are many known instances of the founder effect in human populations, including

- tyrosinemia in the Québécois of the Saguenay–Lac-Saint-Jean region (see Appendix 1.10A: Using Pedigree Analysis to Solve a Genetic Mystery [BLM])
- limb-girdle muscular dystrophy in Manitoba Hutterites
- retinitis pigmentosa on the island of Tristan da Cunha
- Ellis-van Creveld syndrome in the Pennsylvania Amish community

Resource Links

- Jones, Thomas C. “PopGen Fishbowl 1.0.” Virtual Ecology. *Population Genetics*. <http://faculty.etsu.edu/jonestc/virtualecology.htm>.

  This population genetics simulation contains the tools to conduct virtual experiments violating all the assumptions of the Hardy-Weinberg principle.

- Oklahoma State University. “Speciation Tutorial.” 18 Nov. 2010. *Biology 1114*. <http://zoology.okstate.edu/zoo_lrc/biol1114/tutorials/Flash/life4e_15-6-OSU.swf>.

  This animation illustrates the effects of changing the Hardy-Weinberg principle conditions on a population.

- PBS Online. “Sex and the Single Guppy.” *Evolution*. <www.pbs.org/wgbh/evolution/sex/guppy/low_bandwidth.html>.

  This website examines the interplay between natural and sexual selection in a population of wild guppies.

- Virtual Ecology. *Virtual Ecology Project*. <http://faculty.etsu.edu/jonestc/virtualecology.htm>.

MECHANISMS FOR GENETIC VARIATION

SPECIFIC LEARNING OUTCOME

B12-3-09: Discuss how genetic variation in a gene pool can be altered. (GLOs: D1, E1, E3)

Examples: natural selection, gene flow, genetic drift, non-random mating, mutation . . .

Suggestion for Assessment

At the end of the lesson, ask students to describe the most significant point made during the lesson that contributed to their learning (Keeley). The POMS (point of most significance) can be made orally or in writing. Analyze students' responses to determine whether instructional adjustments need to be made. Let students know you will be using the information to plan the next lesson to benefit them. This will help them realize that you are taking their responses seriously, and they will respond thoughtfully and with more detail in the future.

Population Bottlenecks and Endangered Species—Case Study (U2, P3)

See Appendix 3.14A: Population Bottlenecks and Endangered Species—Case Study (BLM) and Appendix 3.14B: Population Bottlenecks and Endangered Species—Case Study (Answer Key) for a learning activity about the endangered whooping crane.

Suggestion for Assessment

Assess students' responses for conceptual understanding, and provide descriptive feedback as to how they could be improved.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

NOTES

SPECIATION

SPECIFIC LEARNING OUTCOME

B12-3-10: Describe how populations can become reproductively isolated. (GLOs: D1, E2)
Examples: geographic isolation, niche differentiation, altered behaviour, altered physiology . . .

SLO: B12-3-10

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

You may wish to discuss with students the definition of species. (See learning outcomes B12-4-01 and B12-4-02 for more information.) The evolutionary biologist Ernst Mayr defined a *species* as a reproductive community of populations (reproductively isolated from others) that occupies a specific niche in nature.

BACKGROUND INFORMATION

When a part of a population becomes geographically isolated from the parent population, *allopatric speciation* can occur. Geographic isolation can occur due to the formation of physical barriers (e.g., mountains, canyons, rising sea levels, glaciers). The physical barrier prevents gene flow between the two populations. If the different populations are subjected to different natural selection pressures, allele frequencies for genes will change. The two populations may accumulate substantial genetic differences so that they become reproductively isolated and are unable to interbreed; therefore, two distinct species result.

When the gene flow between members of a population is restricted due to ecological isolation (niche differentiation), *sympatric speciation* can occur. Some members of a population may be better adapted to a slightly different habitat in an ecosystem, and begin to specialize in that habitat. Different selective pressures in the two habitats lead to genetic changes in the organisms. The two populations become reproductively isolated, and two distinct species result, even though there are no physical barriers separating the population.

Alterations in behaviour can lead to reproductive isolation. Should a group of nocturnal mammals become active during the day, they may no longer interbreed with their counterparts who are active at night. Chromosome mutation can also result in reproductive isolation. A malfunction in meiosis can lead to polyploidy (multiple copies of chromosomes) in a plant. Because plants can reproduce asexually and self-pollinate, the new polyploid can reproduce, even though it is reproductively isolated from its parent(s).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

ACTIVATE

Darwin's Finches

Provide students with pictures or diagrams of some of the 14 Galapagos Islands finches (with their beaks showing), as well as information about the diet of each of the species illustrated. Ask students to hypothesize how these differences evolved from one ancestral species.

ACQUIRE/APPLY

Stages of Allopatric Speciation—Jigsaw (U2, G1, G3)

The Jigsaw (Aronson et al.) is a cooperative learning strategy that enables students to become experts on part of a topic, which they share with others.

Divide the class into four groups, and assign to each home group a particular stage in the process of allopatric speciation:

- stage 1: two populations with normal gene flow
- stage 2: gene flow is prevented by a geographical barrier
- stage 3: genetic differences accumulate
- stage 4: two populations are reproductively isolated

Each group investigates the characteristics and events of the assigned stage and prepares a summary. One student from each group then moves to another group, so that each new group has one expert from each of the previous groups. Each expert shares his or her summary with the new group members. In this way, all members of the class receive the summaries of all the groups. If paper copies of the summaries are provided, the experts should be prepared to discuss the important points of their respective summaries. For more information about the Jigsaw strategy, see *SYSTH* (p. 3.20).

SPECIATION

SPECIFIC LEARNING OUTCOME

B12-3-10: Describe how populations can become reproductively isolated. (GLOs: D1, E2)

Examples: geographic isolation, niche differentiation, altered behaviour, altered physiology . . .

Suggestion for Assessment

Group work skills can be assessed with a checklist. Refer to Appendix 1.13: Collaborative Process—Assessment (BLM).

The Process of Speciation (U1)

Use actual or hypothetical examples to complement a discussion of the process of speciation. Remind students that new species result when members of a population become reproductively isolated from one another and no longer interbreed to produce fertile offspring in their natural environment.

Use note-taking strategies such as the following to provide students with processing time to enhance their conceptual understanding:

- **10 + 2 Note Taking:** Present information for 10 minutes, and then have each student summarize or discuss the material with a partner for two minutes.
- **Three-Minute Pause:** Lecture for a period of time, and then pause for three minutes to allow students to process information with a partner or a small group.

Resource Link

- PBS Online. "An Origin of Species." *Evolution*. <www.pbs.org/wgbh/evolution/darwin/origin/>.
  This website allows students to see how a new species can evolve by observing natural selection and adaptive radiation in action.

Suggestion for Assessment

Pose the following question to students at the end of the lesson:

- How has your understanding of the term *speciation* changed in this lesson?

Give students five minutes to respond in their notebooks.

This quick formative assessment provides information about what students learned in a particular lesson. Students' responses should indicate a clearer understanding of the biological definition of *speciation*.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Speciation—Chain Concept Map (U2)

Provide students with the following list of key terms related to speciation:

- adapt
- gene pool
- interbreed
- population
- reproductive isolation
- selection
- speciation
- species

Students use these key terms, and any others they might wish to add, to create a Chain Concept Map that illustrates the process of speciation. Students may base their concept maps on a type of speciation (e.g., allopatric, sympatric) or on a real or hypothetical example (e.g., Darwin's finches, geographic isolation due to the formation of an inland sea). Inspiration software can be used to create concept maps. For more information on concept maps, refer to *SYSTH* (pp. 11.11–11.18).

Suggestion for Assessment

Assess students' Chain Concept Maps for logic in the layout and linkages, as well as for accurate use of terminology, and adjust teaching to address any difficulties identified.

CONVERGENT AND DIVERGENT EVOLUTION

SPECIFIC LEARNING OUTCOME

B12-3-11: With the use of examples, differentiate between convergent evolution and divergent evolution (adaptive radiation). (GLOs: D1, E1)

SLO: B12-3-11

SUGGESTIONS FOR INSTRUCTION

BACKGROUND INFORMATION

Divergent evolution (also known as *adaptive radiation*) is the process in which an ancestral species gives rise to a number of new species that are adapted to different environmental conditions. This often occurs when a species colonizes a new environment in which there are unoccupied ecological niches. For example, the adaptive radiation of Hawaiian honeycreepers and Darwin's finches occurred on islands. In other cases, adaptive radiation occurred after the extinction of many other species. The rapid increase in the number of species of mammals took place after the mass extinction of the dinosaurs.

Convergent evolution is the process in which different organisms that live in similar habitats become more alike in appearance and behaviour. As they encounter similar environmental pressures, the organisms develop analogous structures. For example, dolphins and sharks live in the water and both use their tails for propulsion. However, their tails are analogous structures with different origins. Sharks move their tails side to side, while dolphins move their tails up and down. Similarly, bat, butterfly, and bird wings are analogous structures.

ACTIVATE

Vocabulary: Recall and Predict

Pose the following questions to students and have them use their prior vocabulary knowledge to predict the meaning of new terminology:

- Can you recall the term *homologous*? Hint: Think of homologous chromosomes. What does *homologous* mean? (similar or related)
- Based on your knowledge of homologous chromosomes, can you predict to what *homologous structures* refer? (similar or related structures in organisms—e.g., human arm, bird wing, dog foreleg)
- What does the term *analogous* mean? Hint: Think of the word *analogy*. (partial similarity, corresponding in some manner)
- Can you predict to what structures *analogous structures* refer? (structures correspond in function, but are not related in origin—e.g., butterfly wing, bird wing)

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

ACQUIRE/APPLY

Homologous and Analogous Structures—Demonstration (U1)

Obtain samples of bird wings (e.g., turkey, chicken, duck) and samples of insect wings (e.g., butterfly, moth, dragonfly).

- Use the bird wings to illustrate homologous structures. Describe the structure and function of a bird's wing. Have students identify the homologous structures in the various bird wings.
- Present the insect wings to students. Describe the structure and function of an insect's wing. Ask students to identify the homologous structures in the various insect wings.

Note that homologous structures are evidence that organisms evolved from a common ancestor. The differences among homologous structures are the result of adaptations to different environments.

Suggestion for Assessment

Ask students to compare the bird wings with the insect wings and have them record their ideas. Students should note that the bird and insect wings have similar functions, but their structures are quite different. Bird wings and insect wings are analogous structures. They do not have a common evolutionary ancestor, but have similar functions. Analogous structures are the result of adaptations to a similar environment. Review students' responses with the class to check for understanding.

CONVERGENT AND DIVERGENT EVOLUTION

SPECIFIC LEARNING OUTCOME

B12-3-11: With the use of examples, differentiate between convergent evolution and divergent evolution (adaptive radiation). (GLOs: D1, E1)

Comparing Convergent and Divergent Evolution (U1)

With the use of examples, compare divergent and convergent evolution by focusing on the key differences between the two processes. Differentiate between homologous and analogous structures using pictures, video clips, and/or diagrams. Evidence for evolution is provided for by homologous structures, as they indicate descent from a common ancestor. Analogous structures also give evidence for evolution, as they show how dissimilar organisms can independently adapt to similar environments.

Resource Links

- British Broadcasting Corporation. *BBC Motion Gallery.* <www.bbcmotiongallery.com/>.

  An extensive collection of video footage is available on this website.

- Thanukos, Anna. "Similarities and Differences: Understanding Homology and Analogy." *Understanding Evolution*. University of California Museum of Paleontology. <http://evolution.berkeley.edu/evolibrary/article/similarity_hs_01>.

  This interactive module explores homologies and analogies and why they are important in evolution.

Suggestion for Assessment

Show video clips of a fish swimming and a whale swimming, focusing on the motion of the tails. Ask students whether the tails are homologous or analogous structures and have them explain their reasoning. Adjust instruction to address any difficulties identified.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Homologous and Analogous Structures—Research and Presentation (U2, I1, I2, I3, I4)

Have students research examples of homologous and analogous structures (e.g., Canada goose wing, little brown bat wing, mosquito wing) and prepare reports containing the following information:

- examples of two organisms that share a homologous structure
- a description of the homologous structure
- an explanation of how the difference in structure is an adaptation to a different environment
- an example of an organism that has a structure analogous to one of the homologous structures
- a description of the analogous structure
- an explanation of how the similarity in function is an adaptation to a similar environment

Resource Links

- Manitoba Education. *Information and Communication Technology (ICT): Kindergarten to Grade 12*. <www.edu.gov.mb.ca/k12/tech/index.html>.

  Visit this website for ideas about integrating information and communication technologies across the curriculum.

- ———. "Professional Learning for Teachers." *Literacy with ICT across the Curriculum: A Developmental Continuum*. <www.edu.gov.mb.ca/k12/tech/lict/let_me_try/le_teachers.html>.

  Information on topics such as plagiarism, evaluating web content, copyright, and making a bibliography can be accessed at this website.

CONVERGENT AND DIVERGENT EVOLUTION

SPECIFIC LEARNING OUTCOME

B12-3-11: With the use of examples, differentiate between convergent evolution and divergent evolution (adaptive radiation). (GLOs: D1, E1)

Suggestions for Assessment

Students present their research on homologous and analogous structures. Research findings can be presented as

- written reports
- visual displays (e.g., poster, brochure, bulletin board exhibit, comic strip)
- oral presentations
- multimedia presentations (e.g., podcast, wiki, PowerPoint, video)

Presentation components may vary, depending on the type of presentation. Refer to Appendix 5.8: Checklist for Creating Visuals (BLM) for use with visuals (e.g., posters, collages, graphic organizers) and Appendix 5.9: Oral Presentation—Observation Checklist (BLM).

Develop assessment criteria for the presentation in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. The criteria should include both content and presentation components. The content criteria should include use of key terms and understandings from the unit.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

NOTES

PACE OF EVOLUTIONARY CHANGE

SPECIFIC LEARNING OUTCOME

B12-3-12: Distinguish between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. (GLOs: D1, E3)

SLO: B12-3-12

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Discuss with students that evolutionary theory continues to be refined and expanded as our knowledge of biology grows. The debate over gradualism versus punctuated equilibrium is just one example of the "evolution" of evolutionary theory.

BACKGROUND INFORMATION

The new or modern synthesis of evolutionary theory (sometimes called neo-Darwinism) contains findings from genetics, population biology, paleontology, and, most recently, from evolutionary developmental (evo-devo) biology. Key contributors include the following:

- **Theodosius Dobzhansky** (1900–1975) was one of the biologists initiating modern evolutionary theory that unites the fields of genetics and evolution. He is notable for defining *evolution* as a change in the frequency of an allele in a gene pool, and is famous for his quotation, "Nothing in biology makes sense except in light of evolution" (1973).
- **Ernst Mayr** (1904–2005) was one of the biologists initiating modern evolutionary theory that unites the fields of genetics and evolution. His work included the development of the concept of biological species and proposed the mechanism of peripatric speciation.
- **Niles Eldredge** (1943–present) and **Stephen Jay Gould** (1941–2002) proposed the theory of punctuated equilibrium, which hypothesizes that changes in species can occur relatively quickly, with long periods of little change (equilibrium) in between.

Gradualism describes the pattern of slow and gradual evolutionary change over long periods of time. Populations slowly diverge from one another due to differing selective pressures. The changes result in transitional forms that are seen in the fossil record. Examples in the fossil record include the evolution of the trilobites.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

Punctuated equilibrium describes the pattern of long stable periods in which species stayed much the same. These periods were interrupted (punctuated) by short periods in which the quick pace of evolution rapidly resulted in the formation of new species. The stimulus for evolution is a sudden significant change in the environment. The fossil record shows that rapid bursts of evolution have often followed mass extinctions (e.g., the Cretaceous extinction of the dinosaurs was followed by the rapid increase of mammalian species).

ACTIVATE

How Fast Does Evolution Occur?—Brainstorming

Introduce the topic of the pace of evolutionary change by posing the following questions to students:

- Have you ever wondered how fast evolution occurs?
- Does it occur at the same rate all the time?

Provide students with time to think about these questions individually, and ask them to record their thoughts in their notebooks.

PACE OF EVOLUTIONARY CHANGE

SPECIFIC LEARNING OUTCOME

B12-3-12: Distinguish between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. (GLOs: D1, E3)

ACQUIRE/APPLY

How Fast Does Evolution Occur?—Class Discussion (U2, G2)

Engage the class in a discussion of the pace/rate of evolutionary change, pointing out that the fossil record shows that some groups of organisms seem to have remained unchanged for millions of years. Ask students to come up with suggestions as to why the rate of evolution in organisms such as the cockroach, shark, and horsetail (*Equisitum*, a type of plant) is so slow. Possible answers include the following:

- stabilizing selection tends to keep allele frequencies relatively constant, thereby limiting evolution
- environmental conditions remained fairly constant
- few chromosomal mutations have occurred

Then, indicate that the fossil record shows that some groups of organisms seem to have undergone rapid speciation events. Ask students to come up with suggestions as to why some species evolved so rapidly. Examples include the adaptive radiation in the Galapagos Islands finches, the Cambrian explosion of animal phyla, and the rise of the mammals in the Tertiary period. Possible answers include the following:

- genetic drift in a small isolated population
- mass extinction of many life forms (e.g., dinosaurs)
- rapidly changing environmental conditions (e.g., meteor strike, glaciation period)
- exploitations of new niches (due to extinction or colonization)

Suggestion for Assessment

Using information gathered from the class discussion, students complete a Compare and Contrast frame for gradualism and punctuated equilibrium (refer to *SYSTH*, pp. 10.15–10.18). Students can compare their completed frames and provide each other with feedback (peer assessment). For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

Punctuated Equilibrium versus Gradualism (U1)

With the use of illustrations, differentiate between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. Note that these are extreme models. The majority of evolutionary biologists believe that some aspects of both models occur during the evolutionary history of a species. At some points there is gradual change, due to stabilizing selection and unchanging environmental conditions. At other points, genetic drift, directional selection, sudden environmental changes, or co-evolution can lead to rapid changes.

Suggestion for Assessment

Use the Thumbs strategy—thumbs up (I get it), thumbs down (I don’t get it), and thumbs sideways (I’m not sure I get it)—to check students’ understanding. This quick formative assessment can be used to adjust the pace of instruction.

The Pace of Evolutionary Change—Demonstrating Understanding (U2, I4, N1)

Pose the following questions to students at the end of a lesson:

- How do proponents of punctuated equilibrium explain the scarcity of transitional forms (missing links) in the fossil record?
- How does their explanation differ from that offered by proponents of gradualism?

Give students five minutes to respond in their notebooks.

PACE OF EVOLUTIONARY CHANGE

SPECIFIC LEARNING OUTCOME

B12-3-12: Distinguish between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. (GLOs: D1, E3)

Suggestion for Assessment

Use this learning activity as a quick formative assessment of what students learned in a particular lesson. Students' responses should include the following:

- Proponents of punctuated equilibrium argue that transitional forms between species are missing because evolution occurs so rapidly in a very short period of time.
- Gradualists believe that transitional forms of organisms or missing links between species are missing from the fossil record because they are rare.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

NOTES

NOTES

Unit 3:
Evolutionary Theory and Biodiversity

Appendices

Appendix 3.1: The Nature of Science—Evolution (Teacher Background)

Non-scientists may confuse two aspects of the term *evolution*. Some may believe that evolution is only a theory, and therefore is not as believable as a law. It is important to understand that theories are explanations of observed phenomena and supported by a large body of evidence and experimentation. Theories are never "proven" into laws; they continue to be refined as more evidence supporting them is accumulated, or rejected when a better explanation of phenomena (another theory) is proposed. Laws are generalizations or patterns in nature (e.g., Boyle's law, Newton's laws of gravity, the laws of thermodynamics), often expressed as mathematical relationships.

Some difficulties associated with evolution arise when the distinction is made between the reality that evolution has occurred (the fact) and the explanation for how evolution occurs (the theory). Evolution is, indeed, a fact. There is a massive body of evidence in the fossil record, in embryological, morphological, and biochemical (DNA) studies, and so on, that demonstrates modern organisms evolved from older ancestral organisms, and modern species are continuing to change. What is less certain is the exact mechanism of evolution. Several theories have been suggested to explain this. Charles Darwin proposed a theory of natural selection to explain the mechanism of evolution. Biologists continue to debate the mechanisms of evolution today.

One of the key elements to the nature of science that students must understand is that there are limits to the questions that science can investigate. Science and its methods cannot address moral, ethical, aesthetic, social, and metaphysical questions, as they rely on evidence gained from nature, either directly or through inference. While scientists may have personal opinions on issues related to such questions, science inquiry is unable to provide answers to those questions.

Appendix 3.2A: Evolution Survey (BLM)*

Read the following statements and indicate whether each statement is true or false, in terms of how you think biologists use and understand the term *evolution* today. You do NOT necessarily have to AGREE with the statement for it to be true, as you think biologists see it. The purpose of this survey is to determine the level of understanding on this topic in this class, so that misconceptions can be discussed. In every case below, *evolution* means *biological evolution*.

Statements	**Your Response (True or False)**
1. Evolution was first proposed and explained by Charles Darwin.	
2. Evolution theory has been tested many times, and has always been supported by the evidence.	
3. Evolution is something that happens to individual organisms.	
4. Evolution is a process that involved the origin of life.	
5. Evolution is a scientific fact.	
6. Evolution is the same as natural selection.	
7. Evolution is only a theory.	
8. Evolution is something that happened only in the past; it is not happening now.	
9. The formation of complex structures, like the eye, can be readily explained by evolution.	
10. Science can properly infer what has happened in the past, based on evidence.	

* Source: University of Indiana. “Evolution Survey.” *Evolution and the Nature of Science Institutes*. <www.indiana.edu/~ensiweb/lessons/ev.surv.html> (5 Apr. 2011). Adapted with permission.

Appendix 3.2B: Evolution Survey (Teacher Background)*

This survey can be used to uncover students' misconceptions regarding evolution. It is important to note that students are to indicate whether the statements are true or false according to how they think biologists understand evolution, not whether students agree or disagree with the statements.

Statements	**Your Response (True or False)**
1. Evolution was first proposed and explained by Charles Darwin.	FALSE: Others proposed that species changed over time.
2. Evolution theory has been tested many times, and has always been supported by the evidence.	TRUE: The body of evidence for evolution is extensive and expanding. All observations support it.
3. Evolution is something that happens to individual organisms.	FALSE: Evolution occurs in populations, not individuals.
4. Evolution is a process that involved the origin of life.	FALSE: Evolution deals only with the origin of species.
5. Evolution is a scientific fact.	TRUE: Evolution has been observed directly; there is no evidence against it.
6. Evolution is the same as natural selection.	FALSE: Natural selection is the mechanism by which evolution occurs.
7. Evolution is only a theory.	FALSE: Evolution is a scientifically demonstrated fact.
8. Evolution is something that happened only in the past; it is not happening now.	FALSE: Evolution is ongoing.
9. The formation of complex structures, like the eye, can be readily explained by evolution.	TRUE: Evolution is not a random or accidental process; there are selective aspects.
10. Science can properly infer what has happened in the past, based on evidence.	TRUE: There are no empirical observations of life, living or extinct, that evolution cannot explain.

* Source: University of Indiana. "Evolution Survey." *Evolution and the Nature of Science Institutes.* <www.indiana.edu/~ensiweb/lessons/ev.surv.html> (5 Apr. 2011). Adapted with permission.

Appendix 3.3: The Story of Charles Darwin (BLM)

The story of Charles Darwin is a fascinating one. While he is associated with the study of biology, he had actually graduated from Cambridge University with a degree in theology. He began his university training in medicine, but changed his studies when he found he could not stand the sight of blood.

Darwin's real interest lay in the area of natural history. He enjoyed hiking in the wilderness, observing nature, collecting plant and insect specimens, and classifying them. John Henslow, a botanist who accompanied Darwin on these hikes, recommended him to Robert FitzRoy, the captain of the HMS *Beagle*, as a companion on the voyage around the world. In 1831, the *Beagle* set sail with Charles Darwin onboard.

Over the next five years, Darwin observed and collected geological and biological specimens along the route. The letters and specimens he sent home during the voyage made him a well-known and respected naturalist. Upon his return to England, Darwin spent a number of years compiling his data and having his specimens classified. He became convinced that species could change over time. In 1838, after reading work by Thomas Malthus on the consequences of overpopulation, he had a flash of insight. He was able to propose a mechanism of evolution: natural selection.

Darwin drafted two manuscripts (1842 and 1844) in which he outlined his theory, but withheld them from publication, only showing the manuscripts to trusted friends. Why was Darwin reluctant to publish? Darwin knew his ideas would be controversial, and could be perceived as being contrary to the religious teachings of the time. But this was not the main reason for his reluctance to publish. Darwin recognized that there were two main aspects of his theory that were problematic at the time. He was unable to explain the origin of the variation within populations that natural selection acted upon, as well as the mechanism of the transmission of variation from one generation to the next.

In the mid-1850s, Alfred Russell Wallace conceived the same ideas as Darwin, based on his observations in Indonesia. He wrote a paper and sent it to Darwin to review. This finally spurred Darwin on to agree to the release of his theory. In 1858, Charles Lyell presented Darwin's 1844 essay and Wallace's paper to the public. Darwin's *On the Origin of Species by Means of Natural Selection* was published in 1859. The book is a well-constructed argument for natural selection, backed by considerable evidence.

Appendix 3.4:
Postcards from the *Beagle*—Creative Writing Assignment (BLM)

Introduction

You are to assume the role of Charles Darwin during his five-year voyage on the HMS *Beagle*. While on your travels, you visit many places and see many fascinating things. Whenever you stop at a port, you send letters and notes home to family and friends. Select a region you have just visited, and send a 100-word postcard home to a friend describing your observations and thoughts about what you have seen in that area.

Here are some tips to get you started:

- Remember that Darwin formulated his theory of evolution by natural selection after his voyage was finished.
- Make your postcard clear and concise.
- Provide the name of the region or area you have written about (e.g., Tasmania, Galapagos Islands, Patagonia).
- Include at least one observation and one question or thought that arose in your mind from your observation.

All the postcards will then be fixed to a map of the world, tracing the voyage of the *Beagle*.

Appendix 3.5A: Natural Selection Simulation (BLM)

Introduction

On a distant planet in a galaxy far, far away, live creatures known as foofoos. While all foofoos eat beans, there are variations in their mouth parts. Some foofoos have a tweezer mouth, some have a needle mouth, and some have a clothespin mouth. One year, a new foofoo with a spoon mouth was discovered. These new foofoos are quite rare. In this lab activity, each of you will play the part of a foofoo on the planet and feed on beans.

Purpose

In this simulation, you will model natural selection by using different utensils to capture food.

Materials (possible substitutions)

- dissecting trays (paper plates)—one per group
- large bag of dried beans (e.g., kidney, lima, northern)
- 250 mL beakers (petri dishes, paper cups)—one per student
- clothespins (chopsticks)
- dissecting needles (dissecting pins, tacks)
- spoons
- tweezers

Procedure

1. Work in a group of three or four students. Obtain one dissecting tray for your group and add 100 dried beans to it. Obtain one 250 mL beaker for each group member.
2. Each group member will be provided with a utensil (utensils may vary). It is important to use the utensil to pick up beans as demonstrated by the teacher. Use caution when picking up beans, as some utensils may be sharp. Hold the utensil in one hand, and hold the beaker flat on the table in front of you with the other hand.
3. There will be four feeding times (trials). Each foofoo must eat 20 beans to survive to the next feeding time.
4. When the feeding time begins (as indicated by the teacher), use the utensil to pick up beans from the dissecting tray and place them in your beaker.
5. Count the number of beans "eaten" by each foofoo in your group and record the results in the Data Table that follows.
6. Repeat the procedure for the remaining feeding times and record the results for each trial in the Data Table.

Data Table

Student	Utensil	Trial 1	Trial 2	Trial 3	Trial 4

Analysis and Conclusions

1. Which type of foofoo was the best adapted to its environment? Explain your answer.
2. How does the type of mouth part affect the survival rate of foofoos?
3. What happens to the foofoos that cannot compete well with other foofoos? Explain.
4. How does the foofoo scenario model natural selection?

Appendix 3.5B: Natural Selection Simulation (Teacher Background)

Introduction (read to students)

On a distant planet in a galaxy far, far away, live creatures known as foofoos. While all foofoos eat beans, there are variations in their mouth parts. Some foofoos have a tweezer mouth (demonstrate how to use tweezers to pick up beans), some have a needle mouth (demonstrate), and some have a clothespin mouth (demonstrate). One year, a new foofoo with a spoon mouth (demonstrate) was discovered. These new foofoos are quite rare. In this lab activity, each of you will play the part of a foofoo on the planet and feed on beans.

Purpose

In this simulation, students model natural selection by using different utensils to capture food.

Materials (possible substitutions)

- dissecting trays (paper plates)—one per group
- large bag of dried beans (e.g., kidney, lima, northern)
- 250 mL beakers (petri dishes, paper cups)—one per student
- clothespins (chopsticks)
- dissecting needles (dissecting pins, tacks)
- spoons
- tweezers

Procedure

1. Remind students that exactly 100 beans must be added to the tray.
2. Provide each student with a utensil so that there are at least two different utensils in each group, but only hand out two or three spoons around the class in the first trial. Caution students to use the utensils in the way that was demonstrated so that no student gets injured when using sharp objects. Students must use one hand to hold the utensil; they must use the other hand to hold the beaker on the table in front of them. No lifting or tilting of the beaker is allowed (to reduce giving students an advantage).
3. Tell students that there will be four feeding times (trials), and that each foofoo must eat at least 20 beans to survive. Signal the start and end times of each trial. Students use their utensils to pick up beans from the tray and deposit them into their beaker/dish.
4. For the first trial, give students one minute to pick up the beans. Discuss with students the results of the trial and relate the results to competition, variation, and adaptation.

5. If any foofoos die, students can play the offspring of surviving foofoos. Discuss reproductive success of survivors with students. Give students whose foofoos died spoons or tweezers for the next round.
6. Run three more trials, one of 45 seconds, one of 30 seconds, and one of 15 seconds. At the end of the four trials, the only surviving foofoos will probably be the spoon-mouthed ones. Review the process of natural selection and extinction with students as related to their foofoos.

Analysis and Conclusions

1. Which type of foofoo was the best adapted to its environment? Explain your answer.

   The spoon-mouthed foofoos were best adapted as they were able to survive and reproduce.

2. How does the type of mouth part affect the survival rate of foofoos?

   The foofoos that pick up the most food the fastest are the ones that survive. They are able to outcompete the other foofoos for food.

3. What happens to the foofoos that cannot compete well with other foofoos? Explain.

   The foofoos that cannot compete will die because they cannot get enough food.

4. How does the foofoo scenario model natural selection?

   The best adapted foofoos (spoon-mouthed) survive and reproduce. They are more fit/better adapted (survival of the fittest). The foofoos that are less fit/adapted die and do not reproduce. They become extinct.

Appendix 3.6: Adaptation (Teacher Background)

An *adaptation* is a variation that allows an organism to be better suited to its environment. Organisms that are better adapted to their environment are more “fit,” thereby increasing their chance of survival and successful reproduction. Thus, adaptations are the result of natural selection.

Adaptations can be classified as behavioural, physiological, or structural. *Behavioural adaptations* are associated with how organisms respond to their environment. Examples of ways in which organisms have adapted their behaviour are seasonal migration by monarch butterflies, birds, and caribou; hibernation by bears and garter snakes; the bending of sunflowers toward the sun; and the shedding of leaves in the fall by deciduous trees.

Variations in the metabolic processes of organisms across a species are known as *physiological adaptations*. Antibiotic-resistant bacteria and pesticide-resistant insects developed because some organisms developed adaptations that allowed them to survive in the presence of antibiotics and pesticides.

Structural adaptations affect the shape or arrangement of physical features of organisms. For example, the blowholes of whales and dolphins are relocated nostrils, while the needles of a cactus are modified leaves that both protect the plant and reduce water loss.

Mimicry is one type of structural adaptation that allows one species to resemble another. The large (up to 75 mm) caterpillar larva of the elephant hawk-moth defends itself by mimicking a snake. The swollen segments near the head contain two large “eye spots” that fool insectivorous birds (and people) into thinking it is dangerous.

Camouflage is another type of structural adaptation to the appearance of organisms. Such an adaptation assists organisms to survive by allowing them to blend in with their environments. The stick insects resemble the shrub branches they inhabit. The stripes on tigers help them to blend in to the jungle.

Appendix 3.7: Natural Selection in a Candy Dish (Teacher Background)*

Overview

In this lab activity, students become unwitting subjects in a demonstration about natural selection. Students select candies from a bowl and have the opportunity to think about what brought about the "survival" of some candies. This situation is, of course, artificial both in the sense that the selecting is done by people and the "organisms" being selected are non-living entities with no DNA and no ability to reproduce.

Materials

- large candy dish or bowl
- variety of candies of different shapes, sizes, brand names, flavours, and colours (Note: There should be at least 2 popular candies for each student and plenty of unpopular ones. Be aware of any food allergies students may have.)

Teacher Preparation

- Prepare a list of candies and note their initial quantity in the dish.

Procedure

1. Make the candy dish accessible in advance of the lab activity so students can pick candies over a period of time, or the dish can be passed around the room a few times. You can avoid commenting about it at all, or you can make innocent remarks about providing a treat for the students.
2. After more than half the candy has been removed, gather the class together. Start the discussion by pointing out that there is often great variation among individuals of animal species. For example, students can look around the room and list the characteristics that vary among humans. Then, ask students why variation is significant. (One reason variation is important is that it allows for differential survival of individuals.)
3. Show them the candy bowl and the remaining candies. Count what candies remain and list them on the board. Ask them whether they remember which candies were originally available. Make a list on the board of the original set of candy.

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* Source: Tang, Carol. "Candy Dish Selection." *UCMP Lessons.* University of California Museum of Paleontology. 20 Nov. 2003. <www.ucmp.berkeley.edu/education/lessons/candy_dish.html> (5 Apr. 2011). Adapted with permission.

4. Now ask students to list the traits of the candy they *selected* from the candy dish (e.g., chocolate flavour, large size, favourite brand). These are the traits that led to the removal of certain candies.
5. Make a list now of the traits of the candies that were *not selected* (e.g., bad flavour, small size). These are the traits that allowed the candies to survive being taken.
6. So, the fact that there were different candies with different traits resulted in some candies being eaten and others surviving. This is what natural selection does with individuals in a population. Each individual has unique traits; some traits help an individual survive and some traits do not.

Extension

Continually add candy into the candy bowl according to the proportions left in the bowl. For example, if, after the first round, all the chocolate candy has disappeared but a lot of green licorice is left, add more green licorice but do not add any more chocolate. This will accentuate the loss of favourite candies and the proliferation of the remaining ones. In addition, this extension will simulate the production of new generations, similar to the evolution of populations over time. Another possibility is that students will take their second choice of candies, simulating the natural situation where predators will start consuming another prey item when their favourite prey item is eliminated.

Appendix 3.8A: Natural Selection in Legocarnivora (BLM)

Introduction

Within any given population there is variation. Each individual differs from all other members of its species; some differ more than others. Some individuals have adaptations that allow them to be better suited to their environment than others. In nature, the most fit (best adapted) individuals survive and reproduce. This is process is known as *natural selection*.

Purpose

In this lab activity, you will use coins and number cubes to simulate natural selection of the best adapted arrangement of wheels on a Legocarnivora for travelling the farthest distance.

Materials (per student group)

- 2 sets of Lego® wheels
- 1 block (2 × 12) of Lego
- 12 blocks (2 × 2) of Lego
- 1 ramp (1 m long)
- 1 six-sided number cube
- 1 coin
- 2 one-metre sticks

Procedure

Part A: Parental Generation

1. Build your parental Legocarnivora. On top of each set of wheels, place two 2 × 2 Lego blocks. Connect the two sets of wheels and blocks with the 2 × 12 block of Lego. Refer to Figure 1.
2. Set up your test ramp with a 25° to 35° incline. Make sure there is enough room at the bottom of your ramp so that your Legocarnivora can roll up to two metres.
3. Run your parental Legocarnivora down the ramp. Measure the distance it rolls from the bottom of the ramp and record this in the Data Table.
4. Repeat step 3 for your second trial. Average your results.

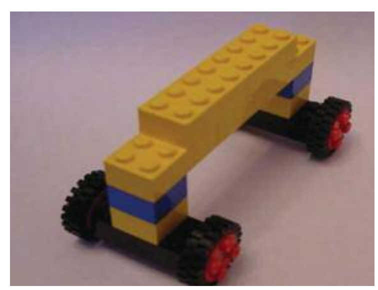

Figure 1: Legocarnivora

Part B: F_1 Generation

1. Your Legocarnivora has three offspring. One is identical to its parent (Offspring A) and the other two are mutations of the parent (Offspring B and Offspring C).
2. Run Offspring A down the ramp (i.e., run the parent again). Measure the distance it rolls from the bottom of the ramp and record this in the Data Table. Repeat for a second trial. Average your results.
3. You will now modify Offspring A to create Offspring B. Flip a coin. If it lands heads up, you will modify the front of the Legocarnivora. If it lands tails up, you will modify the back of the Legocarnivora.
4. Roll a six-sided number cube, and use Table 1: Legocarnivora Modification (see below) to determine how to modify Offspring A to create Offspring B. If at any time the modification is not possible, then your Legocarnivora has "died."

Table 1: Legocarnivora Modification

Cube Roll	Modification
1	add one 2 × 2 block above the wheels
2	add two 2 × 2 blocks above the wheels
3	add three 2 × 2 blocks above the wheels
4	remove one 2 × 2 block from above the wheels
5	remove two 2 × 2 blocks from above the wheels
6	remove three 2 × 2 blocks from above the wheels

5. Build Offspring B and run it down the ramp. Measure the distance it rolls from the bottom of the ramp and record this in the Data Table. Repeat for a second trial. Average your results.
6. Recreate the parental Legocarnivora. Flip the coin and roll the number cube to determine the modifications needed to create Offspring C from the parental Legocarnivora. Refer to Table 1: Legocarnivora Modification.
7. Build Offspring C and run it down the ramp. Measure the distance it rolls from the bottom of the ramp and record this in the Data Table. Repeat for a second trial. Average your results.

Part C: Additional Generations

1. From the three offspring, identify the Legocarnivora that travelled the farthest (on average). This will become the new parent.
2. Repeat steps 1 through 7 of Part B, recording your data for each trial for a total of 10 generations. Note which of your Legocarnivora travels the farthest.
3. Record the mass of your farthest-travelling Legocarnivora.

Observations

Data Table

Legocarnivora	Coin Toss	Cube Roll	# Front Blocks	# Rear Blocks	Distance Rolled		
					Trial 1	Trial 2	Mean
Parent	N/A	N/A	2	2			
Generation 1							
Offspring A							
Offspring B							
Offspring C							
Generation 2							
Offspring A							
Offspring B							
Offspring C							
Generation 3							
Offspring A							
Offspring B							
Offspring C							
Generation 4							
Offspring A							
Offspring B							
Offspring C							
Generation 5							
Offspring A							
Offspring B							
Offspring C							
Generation 6							
Offspring A							
Offspring B							
Offspring C							
Generation 7							
Offspring A							
Offspring B							
Offspring C							
Generation 8							
Offspring A							
Offspring B							
Offspring C							
Generation 9							
Offspring A							
Offspring B							
Offspring C							
Generation 10							
Offspring A							
Offspring B							
Offspring C							

Mass of farthest-travelling Legocarnivora ___________________

Analysis and Conclusions

1. a) Which arrangement of wheels produced the Legocarnivora that travelled the farthest? This is the optimum design.
   b) In which generation did this occur?
2. Is this what you expected to occur? Why or why not?
3. What factor(s) do you think affect the distance the Legocarnivora will travel?
4. a) Of the factor(s) identified, which is environmental in nature?
   b) What effect would a change in the environmental factor have on the optimum design of the Legocarnivora?
   c) Design an experiment to test your prediction.
5. a) Suppose the parent selected in each generation was the one that travelled the shortest distance. How would this affect the optimum design of the Legocarnivora?
   b) Design an experiment to test your prediction.
6. Why were you using the Legocarnivora that travelled the farthest as the new parent for the next generation?
7. Did any of your Legocarnivora die? How is the death of your Legocarnivora an analogy for what happens in nature?
8. How does variation provide the raw material for natural selection?

Appendix 3.8B: Natural Selection in Legocarnivora (Answer Key)

Analysis and Conclusions

1. a) Which arrangement of wheels produced the Legocarnivora that travelled the furthest? This is the optimum design.

   The farthest-travelling Legocarnivora will generally have more blocks on the front than on the rear, or more blocks on the rear than on the front.

   b) In which generation did this occur?

   Answers will vary. The arrangement will usually be in a later generation.

2. Is this what you expected to occur? Why or why not?

   Answers will vary.

3. What factor(s) do you think affect the distance the Legocarnivora will travel?

   The mass of the Legocarnivora and the angle of the ramp will affect the distance travelled.

4. a) Of the factor(s) identified, which is environmental in nature?

   The environmental factor is the angle of the ramp.

   b) What effect would a change in the environmental factor have on the optimum design of the Legocarnivora?

   Answers will vary.

   c) Design an experiment to test your prediction.

   The experimental design should include changing the angle of the ramp and running the experiment again for a few generations.

5. a) Suppose the parent selected in each generation was the one that travelled the shortest distance. How would this affect the optimum design of the Legocarnivora?

   Answers will vary.

   b) Design an experiment to test your prediction.

   The experimental design should include running the experiment again for a few generations, but selecting for the Legocarnivora travelling the shortest distance.

6. Why were you using the Legocarnivora that travelled the farthest as the new parent for the next generation?

   In nature, the best adapted survive and reproduce. The Legocarnivora that travelled the furthest in each generation was the one that was selected for. It was best adapted, so it was the one that "reproduced."

7. Did any of your Legocarnivora die? How is the death of your Legocarnivora an analogy for what happens in nature?

   Yes, some Legocarnivora died. Answers will vary, but should indicate that in nature, sometimes mutations cause variations that are not favourable to the survival of an organism.

8. How does variation provide the raw material for natural selection?

   Individuals with variations that make them better adapted to their environment survive and reproduce in greater numbers than those without such adaptations. Over generations, the number of individuals in a population with the favourable adaptation will increase.

Appendix 3.9: Effects of Selection on Variation (Teacher Background)

Stabilizing selection favours individuals with an "average" value for a trait, and selects against those with extreme values. Note that stabilizing selection tends to keep allele frequencies relatively constant, thereby limiting evolution. In this way, species such as the cockroach and shark have remained stable for millions of years. Human birth weight is an example of stabilizing selection. Until recent medical advances, infants who were too small tended not to survive and infants who were too large died during birth.

Directional selection favours individuals possessing values for a trait at one extreme of the distribution, and selects against the average and the other extreme. Directional selection often operates when an environmental change favours an extreme phenotype. The progressive change in coloration of peppered moths in Great Britain occurred as a result of air pollution (industrial melanism). Over time, the allele frequency for the darker form of the peppered moth increased in the population. The development of antibiotic-resistant bacteria is another example of directional selection. Only those bacteria that can tolerate the presence of an antibiotic survive.

Disruptive selection favours individuals at both ends of the distribution and selects against the average. It is also known as *diversifying selection*. Disruptive selection leads to the formation of distinct subpopulations of organisms. In time, the allele frequencies in the subpopulations may change to the extent that the two groups may no longer be able to interbreed. Marine organisms known as limpets have shell colours that range from white to dark brown. The dark-coloured limpets attached to dark-coloured rocks in the ocean and the light-coloured limpets attached to light-coloured rocks tend to be less visible to predators and have a higher survival rate. The intermediate-coloured limpets (tan coloured) are highly visible to predators and are consumed. The intermediate colour is, therefore, being selected against.

Appendix 3.10A: Investigating Variation (BLM)

Introduction

Many traits have variations within a population. Some variations may increase or decrease an organism's chance of survival in an environment. Natural selection acts upon variation. If a variation helps an organism to survive, the organism is likely to reproduce and pass the variation on to its offspring. Unfavourable variations disappear, because the organisms do not survive to pass the variation to future generations.

Purpose

In this investigation, you will examine variation in the length of dried beans.

Materials (per group)

- 50 dried beans
- ruler with millimetre markings

Procedure

1. Obtain a sample of 50 dried beans. Identify the largest and smallest beans in the sample.
2. Measure the length of the smallest bean to the nearest millimetre. Record its length in the first row of the length column and add a tally mark on the Data Table.
3. Measure the length of the largest bean to the nearest millimetre. In the length column of the Data Table, write the intermediate bean lengths. Then record the length of the largest bean in the final row of the length column and add a tally mark.
4. Measure and tally the remaining 48 beans in your sample.
5. Count the tally marks for each length and record the amount in the group total column.
6. Determine the class total for each length and record the amount in the class total column.

Data Table

Length (mm)	Tally	Group Total	Class Total

Analysis and Conclusions

1. Was there variation in the length of your dried beans? Use specific data to support your answer.
2. Prepare a histogram of the class results. Plot the class total on the y-axis and the length on the x-axis.
3. How would you describe the shape of the graph?
4. What advantage is there for using the class results rather than your group results?
5. What disadvantage could longer length give to the survival of the bean?
6. What disadvantage could shorter length give to the survival of the bean?
7. Complete the following sentence:
   According to the histogram of bean seed length, as the amount of variation from the average length increases, the frequency of that variation _________.
8. If larger bean seeds were a selective advantage, would this be stabilizing, directional, or disruptive selection? Explain.

Appendix 3.10B: Investigating Variation (Answer Key)

Analysis and Conclusions

1. Was there variation in the length of your dried beans? Use specific data to support your answer.

   Yes, there was variation in the length of the beans. Specific examples will vary.

2. Prepare a histogram of the class results. Plot the class total on the y-axis and the length on the x-axis.

   Results will vary from class to class, but generally a bell-shaped curve will result.

3. How would you describe the shape of the graph?

   The result is a bell-shaped curve.

4. What advantage is there for using the class results rather than your group results?

   Using class data gives a larger sample size, which statistically gives a more accurate result.

5. What disadvantage could longer length give to the survival of the bean?

   Larger beans can be found more easily by birds and rodents, and could be eaten.

6. What disadvantage could shorter length give to the survival of the bean?

   Smaller beans may not contain enough food for the germinating embryo.

7. Complete the following sentence:

   According to the histogram of bean seed length, as the amount of variation from the average length increases, the frequency of that variation *decreases*.

8. If larger bean seeds were a selective advantage, would this be stabilizing, directional, or disruptive selection? Explain.

   This would be directional selection. Individuals at one extreme of the distribution are favoured—large seeds are favoured over medium and small seeds. Over time, there would be more and more large seeds, and fewer medium and small seeds.

Appendix 3.11A: Where Did All the Four-Leaf Clovers Go?— Case Study (BLM)

Part A: Introduction

A team of biologists was conducting a long-term study of wildflower distribution in a meadow in a provincial park. A variety of wildflower species were present, such as white clover (*Trifolium repens*), columbine (*Aquilegia canadensis*), and harebell (*Campanula rotundifolia*). During the initial sampling of the plant populations, the biologists noted that the white clovers were usually of the three-leaf variety, but occasionally some four-leaf clovers were found. Four-leaf clovers are a naturally occurring variation of the three-leaf type. Two-leaf and five-leaf variations also occur, but these are extremely rare.

One year, the Parks Branch decided to create a new picnic area near the study site. Over the course of several years, the team of biologists noted that the wildflower population in the study area began to change. As more people began to visit the meadow, the number of four-leaf clovers began to decline to the point that they had virtually disappeared from the site. The research team was puzzled. Where did all the four-leaf clovers go?

Part A: Questions

1. What do you think has happened to the four-leaf clovers?
2. Can you design an investigation to test your hypothesis?

Part B: Mystery Solved

The research team determined that the four-leaf clovers had been picked by the picnickers over several years. The team had fenced in an area to protect the clover from tourists, but even then, the four-leaf variety was found on extremely rare occasions. The collecting had taken its toll. In the meadow, it was maladaptive to be four-leafed, but the three-leaf clovers were left alone.

Part B: Questions

1. What happened to the gene pool of the clover to explain why the four-leaf variety almost disappeared?
2. Which type of selection was occurring in the meadow? Explain your answer.
3. Sketch a graph showing the initial distribution of leaf variation in *Trifolium repens*. Indicate the number of leaves on the *x*-axis, and the number of plants on the *y*-axis.
4. Sketch a graph showing the leaf variation in *Trifolium repens* several years later. Indicate the number of leaves on the *x*-axis, and the number of plants on the *y*-axis.

Appendix 3.11B: Where Did All the Four-Leaf Clovers Go?—Case Study (Answer Key)

Part A

1. The four-leaf clovers were being picked by the picnickers.
2. Possible answers could include interviewing picnickers to see whether they are picking the clovers; enclosing an area in the meadow with a fence to prevent the tourists from getting at the clover and see whether the four-leaf type returns; and putting in a video camera to record the picnickers' behaviours.

Part B

1. The clover gene pool gradually changed in favour of the three-leaf type.
2. Artificial selection was taking place. The normal three-leaf type was being selected for, and the extreme variation (four-leaf) type was being selected against.
3. The frequency peaks at the three-leaf variety, and curves indicate some of the four-leaf variety and very few of the two- and five-leaf varieties.
4. The frequency peaks at the three-leaf variety, and now shows only a few of the four-leaf variety, and very few of the two- and five-leaf varieties.

Appendix 3.12A: Population Genetics Calculations (BLM)

In a stable population, the frequency alleles in a population will equal to 1. This can be expressed as $p + q = 1$, where

p = frequency of the dominant allele

q = frequency of the recessive allele

The Hardy-Weinberg principle equation ($p^2 + 2pq + q^2 = 1$) allows us to calculate the frequencies of the three genotypes, where

p^2 = frequency of individuals homozygous for the dominant allele

q^2 = frequency of individuals homozygous for the recessive allele

$2pq$ = frequency of individuals heterozygous genotype

1. A population of mice has a gene made of 90% *M* alleles (black fur) and 10% *m* alleles (grey fur).
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	
Dominant allele	p =	
Homozygous recessive	q^2 =	
Homozygous dominant	p^2 =	
Heterozygous	$2pq$ =	

   b) If there are 500 mice in the population, how many will have grey fur?
   c) If there are 500 mice in the population, how many will be homozygous for black fur?

2. While studying a sample of pea plants, you find that 36 of 400 plants are short (recessive). The rest of the plants are tall.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	
Dominant allele	p =	
Homozygous recessive	q^2 =	
Homozygous dominant	p^2 =	
Heterozygous	$2pq$ =	

   b) Determine the number of heterozygous pea plants present.
   c) Determine the number of homozygous tall pea plants present.

3. The ability to taste PTC (a chemical) is caused by a dominant gene. In a test of 2000 people, 720 people cannot taste the chemical.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	
Dominant allele	p =	
Homozygous recessive	q^2 =	
Homozygous dominant	p^2 =	
Heterozygous	$2pq$ =	

   b) How many of the 2000 people are homozygous dominant?
   c) How many of the 2000 people are heterozygous?
   d) What is the frequency of the recessive allele?
   e) What is the frequency of the dominant allele?

4. In a population, 64% of individuals show the recessive trait.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	
Dominant allele	p =	
Homozygous recessive	q^2 =	
Homozygous dominant	p^2 =	
Heterozygous	$2pq$ =	

   b) If the population has 10,000 individuals, how many show the recessive trait?
   c) If the population has 10,000 individuals, how many show the dominant trait?

5. The frequency of a recessive disorder is 4% in a population.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	
Dominant allele	p =	
Homozygous recessive	q^2 =	
Homozygous dominant	p^2 =	
Heterozygous	$2pq$ =	

   b) What percentage of the population carries the recessive gene?
   c) What percentage of the population is homozygous dominant?

Appendix 3.12B: Population Genetics Calculations (Answer Key)

In a stable population, the frequency alleles in a population will equal to 1. This can be expressed as $p + q = 1$, where

p = frequency of the dominant allele

q = frequency of the recessive allele

The Hardy-Weinberg principle equation ($p^2 + 2pq + q^2 = 1$) allows us to calculate the frequencies of the three genotypes, where

p^2 = frequency of individuals homozygous for the dominant allele

q^2 = frequency of individuals homozygous for the recessive allele

$2pq$ = frequency of individuals heterozygous genotype

1. A population of mice has a gene made of 90% *M* alleles (black fur) and 10% *m* alleles (grey fur).

   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	$q =$	0.10
Dominant allele	$p =$	0.90
Homozygous recessive	$q^2 =$	0.01
Homozygous dominant	$p^2 =$	0.81
Heterozygous	$2pq =$	0.18

   b) If there are 500 mice in the population, how many will have grey fur?

   0.01 × 500 = 5 mice with grey fur

   c) If there are 500 mice in the population, how many will be homozygous for black fur?

   0.81 × 500 = 405 mice homozygous for black fur

2. While studying a sample of pea plants, you find that 36 of 400 plants are short (recessive). The rest of the plants are tall.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	$q =$	0.30
Dominant allele	$p =$	0.70
Homozygous recessive	$q^2 =$	0.09
Homozygous dominant	$p^2 =$	0.49
Heterozygous	$2pq =$	0.42

   b) Determine the number of heterozygous pea plants present.
      0.42 × 400 = 168 heterozygous pea plants
   c) Determine the number of homozygous tall pea plants present.
      0.49 × 400 = 196 homozygous tall pea plants

3. The ability to taste PTC (a chemical) is caused by a dominant gene. In a test of 2000 people, 720 people cannot taste the chemical.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	$q =$	0.60
Dominant allele	$p =$	0.40
Homozygous recessive	$q^2 =$	0.36
Homozygous dominant	$p^2 =$	0.16
Heterozygous	$2pq =$	0.48

   b) How many of the 2000 people are homozygous dominant?
      0.16 × 2000 = 320 people are homozygous dominant.
   c) How many of the 2000 people are heterozygous?
      0.48 × 2000 = 960 people are heterozygous
   d) What is the frequency of the recessive allele?
      60%
   e) What is the frequency of the dominant allele?
      40%

4. In a population, 64% of individuals show the recessive trait.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	0.80
Dominant allele	p =	0.20
Homozygous recessive	q^2 =	0.64
Homozygous dominant	p^2 =	0.04
Heterozygous	$2pq$ =	0.32

   b) If the population has 10,000 individuals, how many show the recessive trait?
   0.64 × 10,000 = 6400 show the recessive trait
   c) If the population has 10,000 individuals, how many show the dominant trait?
   10,000 – 6400 = 3600 show the dominant trait

5. The frequency of a recessive disorder is 4% in a population.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	0.20
Dominant allele	p =	0.80
Homozygous recessive	q^2 =	0.04
Homozygous dominant	p^2 =	0.64
Heterozygous	$2pq$ =	0.32

   b) What percentage of the population carries the recessive gene?
   32%
   c) What percentage of the population is homozygous dominant?
   64%

Appendix 3.13A: Using the Hardy-Weinberg Principle Equation—Investigation (BLM)

Introduction

The Hardy-Weinberg principle equation, expressed as $p^2 + 2pq + q^2 = 1$, allows the calculation of allele and genotype frequencies in a population. In this investigation, you will determine allele and genotype frequencies for a single human trait.

Purpose

In this investigation, you will calculate the frequencies of the dominant and recessive alleles for an inherited trait. You will also compare the frequencies of two alleles with the frequencies of their phenotypes.

Materials

- calculator

Procedure

1. Tongue rolling is controlled by a single gene. Persons homozygous dominant or heterozygous for this trait can roll their tongues. Homozygous recessive persons cannot roll their tongues. Determine whether you can roll your tongue.
2. Indicate your phenotype (tongue roller or non-roller) on the classroom board. Record the class total of rollers and non-rollers in Data Table 1.
3. From the class data, calculate q^2, the fraction of students with the homozygous recessive genotype. This is the number of non-rollers divided by the total number of students in the sample. Record this in Data Table 2.
4. Calculate q, the frequency of the recessive allele, by taking the square root of q^2. Record this in Data Table 2.
5. Determine the frequency of the dominant allele, p, using the formula $p = 1 - q$. Record this in Data Table 2.
6. Calculate p^2, the proportion of students with the homozygous genotype. Record this in Data Table 2.
7. Calculate $2pq$, the proportion of students with the heterozygous genotype. Record this in Data Table 2.

Data Table 1

Total Number of Rollers	Total Number of Non-Rollers

Data Table 2

Proportion with homozygous recessive genotype (q^2)	
Frequency of recessive allele (q)	
Frequency of dominant allele (p)	
Proportion with homozygous dominant genotype (p^2)	
Proportion with heterozygous genotype ($2pq$)	

Analysis and Conclusions

1. What are the frequencies of the alleles that affect tongue rolling in students in the class?
2. a) Is q, the frequency of the recessive allele, larger or smaller than the frequency of people showing the recessive trait?
   b) Why do you think this is so?
3. If you tested 10,000 people, do you think the genotype frequencies in this population would be the same as those in this class? Explain.
4. If all the Hardy-Weinberg principle conditions were met, what would be the next generation's allele frequencies?
5. *Evolution* is sometimes defined as a change in the allele frequency in a population's gene pool. What does this mean?

Appendix 3.13B: Using the Hardy-Weinberg Principle Equation—Investigation (Answer Key)

Analysis and Conclusions

1. What are the frequencies of the alleles that affect tongue rolling in students in the class?

   Answers will vary. See Data Table 2.

2. a) Is q, the frequency of the recessive allele, larger or smaller than the frequency of people showing the recessive trait?

   The frequency of the recessive allele (q) is larger than the frequency of people showing the recessive trait (q^2).

   b) Why do you think this is so?

   If a person has one copy of the recessive allele and one copy of the dominant allele (is heterozygous for the trait), he or she will show the dominant trait. A person must have two copies of the recessive allele to show the recessive trait. Therefore, the frequency of q is composed of people who are heterozygous for the trait and homozygous recessive for the trait.

3. If you tested 10,000 people, do you think the genotype frequencies in this population would be the same as those in this class? Explain.

   It is unlikely that the genotype frequencies would be identical. The larger sample size would be the better representation of the gene pool.

4. If all the Hardy-Weinberg principle conditions were met, what would be the next generation's allele frequencies?

   The allele frequencies would remain the same. The population would be in genetic equilibrium.

5. *Evolution* is sometimes defined as a change in the allele frequency in a population's gene pool. What does this mean?

   This means that when the types of genes and their occurrence in the gene pool change over time, evolution is taking place.

Appendix 3.14A: Population Bottlenecks and Endangered Species—Case Study (BLM)

Introduction

The whooping crane (*Grus americana*) is the tallest bird in North America, standing almost 1.5 m in height, with a wingspan of up to 2.5 m. While populations of "whoopers" were never large, their numbers declined rapidly in the early 1900s from hunting and habitat destruction due to agriculture. In 1941, only about 21 wild whooping cranes were left in the world—15 migrating birds that nested in the Wood Buffalo National Park of the Northwest Territories and six non-migrating birds that died in a storm in 1949. In the 1940s, various agencies in Canada and the United States of America joined together in an effort to save the birds from extinction.

Wildlife refuges and national parks now protect the whooping crane's natural summer breeding area in the Northwest Territories and wintering grounds in coastal Texas. Captive breeding programs have been established in some zoos (including the Calgary Zoo). Other flocks have been established in Florida (non-migratory) and Wisconsin (migratory). By the winter of 2008/2009, the whooping crane population had climbed to 534 captive and wild birds, 247 of which nested in Wood Buffalo National Park. All the Wood Buffalo birds today are descended from the 15 migratory birds of 1941.

Conservation efforts are hampered by a number of factors. About 15 percent of eggs laid in the wild are infertile, possibly as a result of inbreeding. Disease is a problem in some captive breeding populations. Severe climatic events, including hurricanes in Texas and late-spring blizzards in the Northwest Territories breeding grounds, can lead to increased mortality. Predation of newly hatched chicks is always a threat. Power lines and cell towers pose hazards during migration. Habitat disturbance in the Texas wintering grounds is an ongoing concern due to shipping and oil exploration and development. While their numbers have increased through conservation efforts, whooping cranes will continue to be vulnerable due to the small population size.

Questions

1. Whooping cranes are an example of an endangered species that has passed through a population bottleneck. Explain how a population bottleneck can alter the genetic variation in the gene pool of a species.
2. Describe the effect of the population bottleneck on the potential of the whooping cranes to adapt to environmental changes and evolve.
3. How could the population bottleneck affect the ability of the whooping cranes to recover from near extinction?
4. Why should we protect and conserve an endangered species?

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Appendix 3.14B: Population Bottlenecks and Endangered Species—Case Study (Answer Key)

1. Whooping cranes are an example of an endangered species that has passed through a population bottleneck. Explain how a population bottleneck can alter the genetic variation in the gene pool of a species.

   Because the population reaches such a low number of individuals in a population bottleneck, only a few individuals contribute genes to the entire future population of the species. Much genetic variation within the species is lost, and allelic frequencies change significantly in the remaining gene pool.

2. Describe the effect of the population bottleneck on the potential of the whooping cranes to adapt to environmental changes and evolve.

   The lack of genetic variation reduces the ability of the whooping cranes to adapt to environmental changes. There is little variation upon which natural selection can act.

3. How could the population bottleneck affect the ability of the whooping cranes to recover from near extinction?

   No matter how many whooping cranes there are, the species will always be at risk of extinction. Their genetic homogeneity makes them potentially more sensitive to disease and genetic conditions associated with inbreeding.

4. Why should we protect and conserve an endangered species?

   Answers may vary. They may include points such as the following:

   - *Humans caused the whooping crane numbers to decline by hunting them and destroying their habitat.*
   - *Our actions caused the whooping crane's gene pool to become a gene puddle.*
   - *The human population has become so large and is consuming so many resources that we are forcing our neighbours out of their homes.*
   - *We should practise good stewardship and preserve our world for future generations.*

UNIT 4:
ORGANIZING BIODIVERSITY

Unit 4: Organizing Biodiversity

Specific Learning Outcomes

B12-4-01: Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02: Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

B12-4-03: Describe the dynamic nature of classification. (GLOs: A1, A2)

Include: different systems and current debates

B12-4-04: Describe types of evidence used to classify organisms and determine evolutionary relationships. (GLOs: A2, A5)

Examples: fossil record, DNA analysis, biochemistry, embryology, morphology . . .

B12-4-05: Compare the characteristics of the domains of life. (GLOs: D1, E1)

Include: Archaea (Archaebacteria), Bacteria (Eubacteria), and Eukarya

B12-4-06: Compare the characteristics of the kingdoms in the Eukarya domain. (GLOs: D1, E1)

Include: cell structure, major mode of nutrition, cell number, and motility

B12-4-07: Investigate an evolutionary trend in a group of organisms. (GLOs: C2, C5, C6, E1)

Examples: hominid evolution, vascularization in plants, animal adaptations for life on land . . .

DEFINING BIODIVERSITY AND SPECIES

SPECIFIC LEARNING OUTCOMES

B12-4-01: Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02: Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

SLO: B12-4-01
SLO: B12-4-02

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 6 Science, students developed an appreciation for the diversity of living things. They provided examples of a variety of animals (vertebrate and invertebrate) to illustrate their diversity, and observed and described the diversity of living things within the local environment.

Students investigated the complex interactions between organisms and their environment in Grade 7 Science. They defined ecosystem and provided examples of a range of ecosystems.

In Grade 10 Science, students examined the relationships present in ecosystems to investigate issues related to sustainability, and explored the concepts and implications of species biodiversity. They observed and documented a range of organisms that illustrate the biodiversity of a local or regional ecosystem, and explained how the biodiversity of an ecosystem contributes to its sustainability.

TEACHER NOTE

Biodiversity can be defined as the range of life in an area. It includes not only the diversity among species, but also the diversity within a species. Review with students the importance of genetic diversity (variation) within a species and the importance of biodiversity to ecosystems. Students will be familiar with the term *species*, but may not have explored the topic in depth.

ACTIVATE

Sticky-Note Ecosystems

Divide the class into small groups of two to four students and provide each group with a small package of sticky notes. Give students two minutes to brainstorm and record the names of as many types of organisms as possible, writing the name of one organism per sticky note. Students should try to give as specific a name as possible (e.g., beluga whale instead of whale, bald eagle instead of bird, elm instead of tree). Ask students to include various types of organisms (e.g., plants, animals, fungi) from different ecosystems. If students do not know the name of an organism, they can describe it.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

List different types of ecosystems on the board (e.g., lake, urban, boreal forest). Then ask students to group their organisms according to the ecosystems in which they would be found. Each group then posts their organisms in the appropriate ecosystem.

Examine the sticky-note ecosystems with the class and pose questions such as the following:

- Are any organisms found in more than one ecosystem?
- Which types of organisms are not represented in your ecosystems (e.g., decomposers, producers, consumers)?
- How diverse are your ecosystems? (How many different species are found in your ecosystems?) Relate this to biodiversity.
- Would there be diversity in each of the types of organisms you have listed? Explain. (Yes, there would be genetic diversity.)

ACQUIRE/APPLY

First Word (U2)

Review with students the meaning of the term *biodiversity*, and have them write the word vertically down a page in their notebooks. Students then construct statements about biodiversity that begin with each letter in the word to develop an acrostic.

DEFINING BIODIVERSITY AND SPECIES

SPECIFIC LEARNING OUTCOMES

B12-4-01: Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02: Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

Example

Biodiversity is the range of life in an area.
I
O
D
I
Variation is the source of genetic diversity.
E
R
Species are organisms that share a common gene pool.
I
T
Y

Suggestion for Assessment

Scan the First Word acrostics to determine what students already know (content and terminology), and identify any misconceptions that students may have. The information can be used to plan instruction (formative assessment). The acrostics can be saved for analysis and reflection at the end of the unit. (See Last Word, learning outcome B12-4-07.)

Biodiversity—Concept Overview (U1)

Graphic organizers enhance students' learning, as they assist students in clarifying their thinking. Have students complete a Concept Overview for the concept of biodiversity. For more information, refer to *SYSTH* (pp. 11.22–11.25, 11.37).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

Suggestion for Assessment

Completed Concept Overviews can be peer assessed or handed in for teacher feedback. As this learning activity is intended as a formative assessment to check student understanding, no mark is required. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

Definition of a Species—Class Discussion (U2, N3)

Provide students with pictures of the eastern meadowlark and the western meadowlark. Ask them whether they think the two birds are members of the same species or are different species. While the two birds may look the same, they are, in fact, two different species. The eastern meadowlark (*Sturnella magna*) lives in eastern Canada, while the western meadowlark (*Sturnella neglecta*) lives in the Prairie provinces. Discuss with students the difficulties in determining the definition of a species (i.e., hybrids, phenotypic variation within a species, non-interbreeding subpopulations). For more information, refer to Appendix 4.1: Definition of a Species (Teacher Background).

Resource Links

- Encyclopedia of Life. Home Page. <www.eol.org/>.
  This is an online reference and database of all currently known species.
- Tree of Life Web Project. Home Page. <www.tolweb.org/tree/>.
  Refer to this website for information about biodiversity, characteristics of different groups of organisms, and their evolutionary history.

DEFINING BIODIVERSITY AND SPECIES

SPECIFIC LEARNING OUTCOMES

B12-4-01: Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02: Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

Suggestion for Assessment

Ask students to complete a Two-Minute Paper in the last few minutes of the class. Provide them with two questions to respond to, and have them record their individual responses on a piece of paper.

Questions could include the following (Keeley):

- What was the most important thing you learned today?
- What did you learn today that you didn't know before class?
- What important question remains unanswered for you?
- What would help you to learn better tomorrow?

Review students' responses, looking for areas of confusion, and address the questions during the next class (formative assessment).

Something's Fishy in Paxton Lake: Speciation in Sticklebacks—Case Study (U2, S1, G1, G2, G3)

In the case study "Something's Fishy in Paxton Lake: Speciation in Sticklebacks" by Joan Sharp (available on the National Center for Case Study Teaching in Science website), students work in groups to decide whether two populations of sticklebacks represent separate species. Encourage students to use effective reading strategies to acquire new knowledge and information from the text when reading a case study. This includes activating their prior knowledge before reading the case study, taking some form of notes while reading, and having an opportunity to discuss and/or reflect on what they read in the case study.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

Resource Links

- National Center for Case Study Teaching in Science, University at Buffalo. Home Page. <http://sciencecases.lib.buffalo.edu/cs/>.

  This website provides access to a variety of case studies, which teachers can modify or adapt for classroom use, subject to the specified usage guidelines. Teaching notes and answer keys for the case studies are available free of charge. To access the answer keys, users are required to register for a password.

- Sharp, Joan. "Something's Fishy in Paxton Lake: Speciation in Sticklebacks." *Back Catalog*. National Center for Case Study Teaching in Science. 2 Nov. 2001. <http://ublib.buffalo.edu/libraries/projects/cases/stickleback/stickleback.html>. Case Teaching Notes are available at <http://ublib.buffalo.edu/libraries/projects/cases/stickleback/stickleback_notes.html>.

Suggestion for Assessment

Whatever the form of assessment used, students should be made aware of the criteria beforehand. Answers to the exercises can be assessed by the teacher, or shared and discussed with other students/groups (peer assessed). For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

DEFINING BIODIVERSITY AND SPECIES

SPECIFIC LEARNING OUTCOMES

B12-4-01: Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02: Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

Biodiversity—Demonstrating Understanding (U1, N3)

Pose the following questions to students at the end of the lesson:

- Why can it be difficult to define what a species is?
- What is the difference between biodiversity and genetic diversity?

Give students five minutes to respond in their notebooks.

Suggestion for Assessment

This learning activity provides a quick formative assessment of what students learned in a particular lesson.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

NOTES

Classifying Organisms

Specific Learning Outcome

B12-4-03: Describe the dynamic nature of classification. (GLOs: A1, A2)

Include: different systems and current debates

SLO: B12-4-03

Suggestions for Instruction

Entry-Level Knowledge

In Grade 6 Science, students were introduced to classification systems, and they constructed and used their own systems, as well as those developed by others. In doing so, students learned to recognize the advantages and disadvantages of classification systems in organizing information.

Teacher Note

Great progress has been made in the last several decades in clarifying evolutionary relationships among living things. Some of the information presented in textbooks is in conflict with the more recent revisions to the tree of life.

Students will be most familiar with traditional systematics (Linnaean classification) of organisms. This method classifies organisms into taxa (groups) using morphological and physiological similarities, but does not fully reconstruct evolutionary relationships among organisms. For example, birds and dinosaurs are organized into separate classes (Aves and Reptilia).

Introduce students to *phylogenetic systematics (cladistics)*, a method developed by German biologist Willi Hennig (1913–1976). This method uses phylogenetics as the determining factor in classification, emphasizing descent and common ancestry in order to determine the evolutionary history of groups of organisms. *Cladograms* are diagrams that show evolutionary relationships based on shared inherited features, and do not rank organisms into phyla, class, order, and so on. Organisms are organized in *clades*, groups of organisms that include an ancestor and all descendents of that ancestor. As a result, birds are placed in the same clade as dinosaurs (*Dinosauria*) as they share a common ancestor.

Note that the shift to phylogenetic systematics is in progress. The Linnaean classification system is still used in many textbooks. Diagrams of phylogenetic trees, evolutionary trees, or the tree of life may or may not be true cladograms.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

BACKGROUND INFORMATION

- *Classification* is a general term for grouping things in an organizational scheme.
- *Taxonomy* is the science of naming life forms.
- *Phylogenetics* is the process of determining the evolutionary history and relationships among the various forms of life through time.
- *Systematics* deals with the diversity of life and the relationships among life forms, both living and extinct. New information obtained from DNA and RNA sequencing has led to sweeping changes in the classification of organisms since 1990.
- *Traditional systematics* (Linnaean classification), based on morphological differences between groups, is being replaced by *phylogenetic systematics* (cladistics), which reflects evolutionary relationships. Traditional groupings such as family and class are falling out of use.

For more information on the dynamic nature of classification as an example of how the use of new and improved technologies have led to changes in the entire system of classification, refer to Appendix 4.3: The Changing Nature of Classification (Teacher Background).

Resource Link

- Thanukos, Anastasia. "A Name by Any Other Tree." *Evolution: Education and Outreach* 2.2 (2009): 303–09. Available on the SpringerLink website at <www.springerlink.com/content/k176638503p63017/fulltext.pdf>.

  This article discusses the changing nature of classification to show evolutionary relationships.

CLASSIFYING ORGANISMS

SPECIFIC LEARNING OUTCOME

B12-4-03: Describe the dynamic nature of classification. (GLOs: A1, A2)

Include: different systems and current debates

ACTIVATE

Think-Pair-Share

Pose the following question to students:

> Think about your home, school, and neighbourhood. Can you think of any examples of classification systems in use in your home, school, or environment?

Give students time to think of examples individually. Students then pair up with a partner to discuss their ideas.

Examples of classification systems may include the following:

- library (e.g., Dewey decimal system)
- grocery store (e.g., aisles, departments)
- DVD rental shop (e.g., alphabetical order)
- students in school (e.g., grades)
- clothing at home (e.g., sock drawer, shirt drawer)

ACQUIRE/APPLY

Species and Systematics—Demonstration (U1)

For this demonstration, use a variety of vegetables to introduce and discuss binomial nomenclature and systematics. Refer to Appendix 4.4: Species and Systematics—Demonstration (Teacher Background).

Critical Thinking (U2)

Categorical logic is the basis for classification systems. It examines relationships according to groups or categories of things. For example, the statement “all dogs are mammals” informs us that the entire group of dogs is contained within the larger group of mammals.

Categorical logic uses deductive reasoning to reach a conclusion. The conclusion is valid only if the evidence provided is true and the reasoning used to reach the conclusion is correct. See Appendix 4.5: Categorical Reasoning in Biology (BLM) for the student learning activity.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

Suggestion for Assessment

Students can compare their completed work and provide each other with feedback (peer assessment). For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM). Remind students to talk about the work, not the person, and to make specific suggestions describing what is good about the work and what could be improved.

What Is Cladistics? (U1, N1)

Introduce students to cladistics and cladograms. Cladistics is now accepted as the best method for phylogenetic analysis, as it provides an explicit and testable hypothesis of evolutionary relationships among organisms.

Use note-taking strategies such as the following to provide students with processing time to enhance their conceptual understanding:

- **10 + 2 Note Taking:** Present information for 10 minutes, and then have each student summarize or discuss the material with a partner for two minutes.
- **Three-Minute Pause:** Lecture for a period of time, and then pause for three minutes to allow students to process information with a partner or a small group.

CLASSIFYING ORGANISMS

SPECIFIC LEARNING OUTCOME

B12-4-03: Describe the dynamic nature of classification. (GLOs: A1, A2)

Include: different systems and current debates

Resource Links

- Peabody Museum of Natural History, Yale University. "Travels in the Great Tree of Life." *Online Exhibitions.* <www.peabody.yale.edu/exhibits/treeoflife/learn.html>.
  This tutorial explains the basics of tree thinking and provides many examples from actual organisms.

- University of California Museum of Paleontology. "Journey into Phylogenetic Systematics." *Phylology of Life.* <www.ucmp.berkeley.edu/clad/clad4.html>.
  This website provides an introduction to the philosophy, methodology, and implications of cladistic analysis.

- ———. "Phylogentic Systematics, a.k.a. Evolutionary Trees." *Understanding Evolution*. <http://evolution.berkeley.edu/evolibrary/article/phylogenetics_01>.
  This tutorial provides information on building, reading, and using evolutionary trees (cladograms).

- ———. "What Did T. Rex Taste Like? An Introduction to How Life Is Related." *Education*. <www.ucmp.berkeley.edu/education/students.php>.
  This interactive module provides an introduction to cladistics and involves students in posing hypotheses about past life based upon evolutionary history.

Suggestion for Assessment

At the end of the lesson, distribute index cards or half sheets of paper. Ask students to describe the "muddiest point" of the lesson—that is, the ideas or parts of the lesson that were confusing or difficult to understand (Gregory, Cameron, and Davies). Let students know you will be using the information to plan the next lesson to benefit them best. At the start of the next lesson, share with students examples of responses that informed your instructional decisions. This will help students realize that you are taking their responses seriously, and they will respond thoughtfully and with more detail in the future.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

Compare and Contrast (U2)

Students complete a Compare and Contrast frame comparing and contrasting traditional systematics (Linnaean classification) and phylogenetic systematics (cladistics). Refer to *SYSTH* (pp. 10.15–10.18, 10.24) for more information and a Compare and Contrast frame.

Suggestion for Assessment

Assess students' Compare and Contrast frames for conceptual understanding, and provide descriptive feedback as to how the frames could be improved.

Classification Systems—Investigation (P1, S1, I4)

A variety of learning activities are available in lab manuals, in textbooks, and on the Internet for developing and using classification systems. Use imaginary or real organisms (not human-made objects such as nuts and bolts) to reflect how modern classification indicates evolutionary history. Refer to Appendix 1.3: Student Lab Skills (Teacher Background) for information on assessing and evaluating student lab skills.

Suggestion for Assessment

Assess responses of students to determine their levels of conceptual understanding and to guide further teaching/learning activity selection (if needed). Refer to Appendix 1.4A: Lab Skills Checklist—General Skills (BLM) and Appendix 1.4B: Lab Skills Checklist—Thinking Skills (BLM).

DETERMINING EVOLUTIONARY RELATIONSHIPS

SPECIFIC LEARNING OUTCOME

B12-4-04: Describe types of evidence used to classify organisms and determine evolutionary relationships. (GLOs: A2, A5)

Examples: fossil record, DNA analysis, biochemistry, embryology, morphology . . .

SLO: B12-4-04

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 6 Science, students identified, based on evidence gathered by paleontologists, similarities and differences between animals living today and those that lived in the past.

BACKGROUND INFORMATION

Traditional Linnaean classification was based on similarities in morphology among species. It artificially grouped organisms into kingdoms, phyla, and so on, and relied on the fossil record, homologies, and embryology to determine relationships between organisms.

Phylogenetic classification (cladistics) uses shared characteristics to attempt to understand evolutionary relationships among organisms. It is now the accepted method for systematic analysis as it is based on ancestor and descent relationships (phylogeny). DNA sequencing and RNA sequencing are important techniques for determining phylogenetic relationships.

ACTIVATE

Class Survey

Pose the following question to students:

- Science textbooks often have tree- or fan-like diagrams showing different groups of organisms. What types of evidence do scientists use to classify organisms and determine evolutionary relationships?

Ask students to share their ideas in class and record their responses on the board. Use the responses to lead students in a discussion of evidence used to classify organisms and determine evolutionary relationships.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Acquire/Apply

Technologies and Tools of Classification—Jigsaw Strategy (U2, I1, I2, I4, G1, G3)

Divide the class into groups, and assign to each group a particular type of evidence used in the science of classification (e.g., fossil dating, DNA analysis). Each group then investigates its classification technology or tool. The groups prepare one-page summaries outlining how their technology or tool is used in classifying organisms and determining phylogenetic relationships.

Using the Jigsaw strategy, arrange students into new groups so that each new group contains one expert from each of the previous groups. Each expert then shares his or her summary with the new group members. In this way, all members of the class receive the summaries of all the groups. If paper copies of the summaries are provided, the experts should be prepared to discuss the important points of their summary. For more information about the Jigsaw strategy, see *SYSTH* (p. 3.20).

Suggestion for Assessment

Students can assess their collaborative process. Refer to Appendix 1.13: Collaborative Process—Assessment (BLM).

DETERMINING EVOLUTIONARY RELATIONSHIPS

SPECIFIC LEARNING OUTCOME

B12-4-04: Describe types of evidence used to classify organisms and determine evolutionary relationships. (GLOs: A2, A5)

Examples: fossil record, DNA analysis, biochemistry, embryology, morphology . . .

Understanding the Evidence (U1)

The use of videos and computer animations that illustrate and describe the evidence used to classify organisms and determine evolutionary relationships can enhance students' conceptual understanding. A wealth of information can be found in a variety of multimedia formats.

The use of a note-taking strategy such as a Note Frame can help students follow a lecture and organize information. For more information, refer to *SYSTH* (p. 11.32).

Resource Links

- PBS Online. "Evolution." *NOVA beta.* <www.pbs.org/wgbh/nova/beta/evolution/>.

  This website has online *NOVA* television episodes, interactives, and the latest news in evolution science, as well as links to other evolution-related websites and resources.

- University of California Museum of Paleontology. "The Evolution of Flight in Birds." *Education*. <www.ucmp.berkeley.edu/education/students.php>.

  This module examines evidence from the fossil records, behaviour, biomechanics, and cladistic analysis to interpret the sequence of events that led to flight in the dinosaur lineage.

- ———. *Online Exhibits*. <www.ucmp.berkeley.edu/exhibits/index.php>.

  This website features exhibits such as "The Paleontology Portal," "Tour of Geologic Time," "History of Life through Time," and "Education Resources." It also offers a range of interactives, lessons, and learning activities.

Suggestion for Assessment

The use of Note Frames assists teachers in monitoring students' understanding (formative assessment). The information can be used to adjust teaching to address difficulties. Students can also compare their Note Frames and provide each other with feedback (peer assessment). For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Museum—Field Trip (U2, P2, I1)

Students can learn about classifying organisms and determining evolutionary relationships by participating in field trips to the Canadian Fossil Discovery Centre, located in Morden, Manitoba, or The Manitoba Museum, located in Winnipeg.

Resource Links

- Canadian Fossil Discovery Centre. Home Page. <www.discoverfossils.com/>.

  This centre has exhibits of Cretaceous marine fossils, including mosasaurs, plesiosaurs, squid, sharks, and seabirds. A dig can be arranged for students to learn field techniques and search for and excavate fossils.

- The Manitoba Museum. "Earth History Gallery." *Museum*. <www.manitobamuseum.ca/main/museum/earth-history-gallery/>.

  This gallery traces Manitoba's geologic past and has fossils of various life forms such as trilobites and a plesiosaur.

Suggestion for Assessment

Have students complete an I Used to Think, But Now I Know reflection after the field trip. Ask students to recall their ideas at the start of the topic discussion, and have them explain how their ideas changed or became more detailed compared to what they knew at the beginning of instruction (Keeley). Students can discuss their reflections with a partner.

DETERMINING EVOLUTIONARY RELATIONSHIPS

SPECIFIC LEARNING OUTCOME

B12-4-04: Describe types of evidence used to classify organisms and determine evolutionary relationships. (GLOs: A2, A5)

Examples: fossil record, DNA analysis, biochemistry, embryology, morphology . . .

Demonstrating Understanding—Are Pigeons Really "Rats with Wings"? (U2)

Pose the following question to students at the end of the lesson:

- While pigeons are often mocked as "rats with wings," pigeons (and all birds) are more closely related to carnivorous dinosaurs such as tyrannosauri and velociraptors than they are to mammals. Some have even called birds "dinosaurs with feathers." What evidence is there for the close relationship between birds and reptiles?

Give students five minutes to respond in their notebooks.

Suggestion for Assessment

This learning activity provides a quick formative assessment of what students learned in a particular lesson. Students' responses may include the following:

- fossils (e.g., archaeopteryx)
- dating of fossils (e.g., radioisotopes such as carbon-14)
- similarities in structure (e.g., presence of wishbone, structure of hip bones)
- fossil records (showing changes over time)
- DNA analysis (e.g., avian DNA is more similar to crocodilian DNA than it is to mammalian DNA)

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

NOTES

DOMAINS OF LIFE

SPECIFIC LEARNING OUTCOMES

B12-4-05: Compare the characteristics of the domains of life. (GLOs: D1, E1)

Include: Archaea (Archaebacteria), Bacteria (Eubacteria), and Eukarya

B12-4-06: Compare the characteristics of the kingdoms in the Eukarya domain. (GLOs: D1, E1)

Include: cell structure, major mode of nutrition, cell number, and motility

SLO: B12-4-05
SLO: B12-4-06

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 6 Science, students identified the five kingdoms (i.e., monerans, protists, fungi, plants, and animals) commonly used for the classification of living things and provided examples of organisms from each kingdom to illustrate the diversity of living things.

TEACHER NOTE

With advances in DNA and RNA sequencing technologies, phylogenetic relationships among organisms are currently subject to intense debate. Extensive changes in classification have been in progress since 1990. These changes can lead to confusion for students when they consult various sources of information. Some textbooks and resources may not provide information about the three-domain classification system, but instead use the five- or six-kingdom system. Other resources may use the term *superkingdom* instead of domain. Consult journals and reputable Internet sites for current information.

BACKGROUND INFORMATION

For more information on the characteristics of the domains of life, refer to Appendix 4.6: The Three Domains of Life (Teacher Background).

Resource Link

- Thanukos, Anastasia. "A Name by Any Other Tree." *Evolution: Education and Outreach* 2.2 (2009): 303–309. Available on the SpringerLink website at <www.springerlink.com/content/k176638503p63017/fulltext.pdf>.

  This article discusses the changing nature of classification to show evolutionary relationships.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

ACTIVATE

Do You Remember?

Ask students to recall the taxa of Linnaean classification (kingdom, phylum, class, order, family, genus, and species) or the mnemonics used to remember the taxa (e.g., Kings Play Chess On Fuzzy Green Stools, Kids Prefer Chocolate Over Fried Green Spinach). Inform students of the revised classification system that now recognizes three domains, and ask them to create a new mnemonic to help them remember the names of the three domains.

ACQUIRE/APPLY

Domains and Kingdoms (U2)

Discuss with students the characteristics and representative organisms of each domain and kingdom, and explain how genetic and biochemical analyses changed biological classification. The use of diagrams to illustrate and describe the relationship among three domains of living things can assist students.

Use note-taking strategies such as the following to provide students with processing time to enhance their conceptual understanding:

- **10 + 2 Note Taking:** Present information for 10 minutes, and then have each student summarize or discuss the material with a partner for two minutes.
- **Three-Minute Pause:** Lecture for a period of time, and then pause for three minutes to allow students to process information with a partner or a small group.

DOMAINS OF LIFE

SPECIFIC LEARNING OUTCOMES

B12-4-05: Compare the characteristics of the domains of life. (GLOs: D1, E1)

Include: Archaea (Archaebacteria), Bacteria (Eubacteria), and Eukarya

B12-4-06: Compare the characteristics of the kingdoms in the Eukarya domain. (GLOs: D1, E1)

Include: cell structure, major mode of nutrition, cell number, and motility

Resource Links

- Tree of Life Web Project. Home Page. <www.tolweb.org/tree/>.

  This website contains information about the diversity of organisms on Earth, including their evolutionary history and characteristics.

- University of California Museum of Paleontology. "History of Life through Time." *Online Exhibits*. <www.ucmp.berkeley.edu/exhibits/historyoflife.php>.

  This collection catalogues life on Earth, focusing on the ancestor/descendant relationships that connect all organisms, past and present.

Suggestion for Assessment

Use the Thumbs strategy—thumbs up (I get it), thumbs down (I don't get it), thumbs sideways (I'm not sure I get it)—to check students' understanding. This quick formative assessment can be used to adjust the pace of instruction.

Building Vocabulary (U1)

Introduce new vocabulary to students as required. Students benefit from assistance with vocabulary before they start to read science texts. The use of a variety of strategies and think-sheet frames (e.g., Word Cycle, Three-Point Approach) can aid students in developing both conceptual and contextual knowledge of the vocabulary of genetics. Refer to *SYSTH* (Chapter 10) for more information on building a scientific vocabulary and for examples of think-sheet frames.

Suggestion for Assessment

Completed think-sheet frames can be peer assessed or handed in for teacher feedback. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM). As this learning activity is intended as a formative assessment to check student understanding, no mark is required.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

Understanding Domains and Kingdoms—Hierarchy Concept Map (U2, G1)

Students work in small groups to create Hierarchy Concept Maps summarizing the characteristics of the domains of life. When provided with the characteristics, students should be able to identify the domain to which an organism belongs.

Students then add the kingdoms of the Eukarya domain to the concept map and summarize the characteristics of each kingdom. When provided with the characteristics, students should be able to identify the kingdom to which an organism belongs (e.g., multicellular, heterotroph, cell walls made of chitin = fungi). Refer to *SYSTH* (pp. 11.16–11.17) for more information on Hierarchy Concept Maps.

Suggestion for Assessment

Assess students' Hierarchy Concept Maps for conceptual understanding, and provide descriptive feedback as to how the concept maps could be improved.

How Have New Technologies Changed Classification?—Demonstrating Understanding (U1, I4, N1)

Pose the following question to students at the end of the lesson:

- How have new technologies, such as DNA analysis and biochemical tests, changed the way organisms are classified?

Give students five minutes to respond in their notebooks.

DOMAINS OF LIFE

SPECIFIC LEARNING OUTCOMES

B12-4-05: Compare the characteristics of the domains of life. (GLOs: D1, E1)

Include: Archaea (Archaebacteria), Bacteria (Eubacteria), and Eukarya

B12-4-06: Compare the characteristics of the kingdoms in the Eukarya domain. (GLOs: D1, E1)

Include: cell structure, major mode of nutrition, cell number, and motility

Suggestion for Assessment

This learning activity provides a quick formative assessment of what students learned in a particular lesson. Students' responses may include the following:

- DNA analysis can determine the relatedness of two species. The more similar the DNA sequences are, the more closely related the organisms are.
- DNA analysis can determine how long ago species began to diverge, using accumulated differences in DNA (molecular clocks).
- Biochemical tests determine the presence of specific molecules in cells. The more similar the specific molecules are, the more closely related the organisms are.
- DNA analysis and biochemical tests determined the Archaea were distinct from other bacteria with which they had previously been grouped. This led to the three-domain classification system.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

NOTES

INVESTIGATING EVOLUTIONARY TRENDS

SPECIFIC LEARNING OUTCOME

B12-4-07: Investigate an evolutionary trend in a group of organisms. (GLOs: C2, C5, C6, E1)

Examples: hominid evolution, vascularization in plants, animal adaptations for life on land . . .

SLO: B12-4-07

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 6 Science, students described the two main groups in the animal kingdom, vertebrates and invertebrates, and provided examples of representative organisms. Students also classified vertebrates as fishes, amphibians, reptiles, birds, and mammals, and provided examples to illustrate the diversity within each group.

TEACHER NOTE

Traditional Linnaean classification separated the extant terrestrial vertebrates into four classes: amphibians, reptiles, birds, and mammals. Three major classes of fish were recognized:

- Agnatha (jawless fishes such as lampreys)
- Chondrichthyes (cartilaginous fishes such as sharks and rays)
- Osteichthyes (bony fishes such as salmon and guppies)

Cladistics takes a different approach that is subject to ongoing debate. Some of the information presented in textbooks is in conflict with the more recent revisions to the tree of life. Consult journals and reputable Internet sites for current information.

A *cladogram* is a visual reconstruction of the evolutionary history of a group of organisms resulting from cladistic analysis. Cladograms appear as branching diagrams based on a sequenced pattern of ancestral (primitive) and derived (advanced) traits. Derived traits distinguish members of one evolutionary branch from another. All taxa are found at the endpoints of the cladogram. Note that some fan-like or tree-like diagrams showing evolutionary relationships are not cladograms, because they show ancestral species located closer to the base/trunk, and present-day species located at the ends of the blades/branches.

Phylogenetic trees and cladograms are dynamic (i.e., they are constantly being revised), based on the biological data used, new mathematical and computational ideas, and current and emerging knowledge.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

ACTIVATE

What's a Fishapod?

Introduce students to *Tiktaalik roseae*, a 375-million-year-old fossil discovered on Ellesmere Island, Nunavut, in 2004. *Tiktaalik* is a transitional species, as it shares characteristics of ancient fish and early tetrapods (hence the term *fishapod*). After analyzing the fossil, the research team asked a Nunavut council of Elders to offer suggestions for a name for the species. They suggested *Tiktaalik*, which is Inuktitut for large freshwater fish.

Resource Link

- The University of Chicago. *Tiktaalik roseae*. <http://tiktaalik.uchicago.edu/>.
  Visit this website for information on the search for and discovery of *Tiktaalik*, including video clips, articles, and teaching tools.

INVESTIGATING EVOLUTIONARY TRENDS

SPECIFIC LEARNING OUTCOME

B12-4-07: Investigate an evolutionary trend in a group of organisms. (GLOs: C2, C5, C6, E1)

Examples: hominid evolution, vascularization in plants, animal adaptations for life on land . . .

ACQUIRE/APPLY

Interpreting Cladograms (U2, S1, I1)

Provide students with a cladogram and have them trace the evolutionary history of a group of organisms (e.g., phylogeny of modern birds from therapod dinosaurs, hominid evolution), identifying the derived traits.

Suggestion for Assessment

Assess students' identification of the derived traits to determine students' levels of conceptual understanding and to guide further teaching/learning activity selection (if needed).

Dissection (P1, S1, S2, S3, S5)

Use a series of dissections or equivalent exercises with dissection software to examine the anatomy and physiology of representative vertebrates and/or invertebrates. Compare adaptations of each group for performing life functions. For example, compare circulation and respiration in earthworms, grasshoppers, squid, and sharks. Note that DNA analysis has replaced comparative anatomy in determining relationships among living things.

Students often find the odour of specimens preserved in formalin/formaldehyde offensive. To reduce the odour, soak the specimens overnight in fresh water. By changing the water a few times, the smell will be minimized.

Suggestion for Assessment

Assess students' lab skills during the investigation using a lab skills checklist. Lab reports can be assessed as well. See Appendix 1.4A: Lab Skills Checklist—General Skills (BLM) and Appendix 1.4B: Lab Skills Checklist—Thinking Skills (BLM). For various ways of writing a laboratory report, refer to *SYSTH* (pp. 11.26–11.29 and 14.11–14.12).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)
Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)
Include: print and electronic sources, resource people, and different types of writing

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)1

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

CT

Investigating an Evolutionary Trend—Research and Presentation/ Culminating Task (U2, P1, S1, I1, I3, I4, N1)

Students research an evolutionary trend in a group of organisms and present their findings to the class. Possible topics include the following:

- hominid evolution
- vascularization in plants
- cephalization in invertebrates
- evolution of flight in birds
- changes in the alternation of generations in plants
- development of the digestive tract in animals
- changes in vertebrate respiration (adaptations to life on land)

An investigation of this sort can be used as a culminating task for the unit, bringing together a number of knowledge and skills and attitudes learning outcomes.

INVESTIGATING EVOLUTIONARY TRENDS

SPECIFIC LEARNING OUTCOME

B12-4-07: Investigate an evolutionary trend in a group of organisms. (GLOs: C2, C5, C6, E1)

Examples: hominid evolution, vascularization in plants, animal adaptations for life on land . . .

Resource Links

- Manitoba Education. *Information and Communication Technology (ICT): Kindergarten to Grade 12*. <www.edu.gov.mb.ca/k12/tech/index.html>.

  Visit this website for ideas about integrating information and communication technologies across the curriculum.

- ———. "Professional Learning for Teachers." *Literacy with ICT across the Curriculum: A Developmental Continuum*. <www.edu.gov.mb.ca/k12/tech/lict/let_me_try/le_teachers.html>.

  Information on topics such as plagiarism, evaluating web content, copyright, and making a bibliography can be accessed at this website.

Suggestions for Assessment

Students prepare and present their research outlining an evolutionary trend in a group of organisms. Research findings can be presented in a variety of formats:

- visual display (e.g., poster, bulletin board exhibit)
- written report
- oral presentation
- multimedia presentation (e.g., PowerPoint, podcast, wiki)

Presentation components may vary, depending on the type of presentation. Refer to Appendix 5.8: Checklist for Creating Visuals (BLM) for use with visuals (e.g., posters, collages, graphic organizers) and Appendix 5.9: Oral Presentation—Observation Checklist (BLM).

Create an assessment rubric for the report/presentation by developing the assessment criteria and performance levels in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. Assessment criteria should include both content and presentation components. Alternatively, provide students with exemplars of strong and weak reports, and have them work in groups to identify possible assessment criteria and define levels of performance. The exemplars can be anonymous samples of student work done in previous years.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

Last Word (U2)

At the end of the unit, students repeat the process outlined in First Word (see learning outcomes B12-4-01 and B12-4-02), using a new page in their notebooks to create Last Word acrostics.

Suggestion for Assessment

After students have completed their Last Word acrostics, refer them to their First Word acrostics. Students compare the two pages and self-assess their work, reflecting on how their conceptual understanding has progressed. The information from Last Word can be used to identify whether further lessons are required (formative assessment).

NOTES

Unit 4:
Organizing Biodiversity

Appendices

Appendix 4.1: Definition of a Species (Teacher Background)

The species is the only taxonomic category with a clear biological identity. The evolutionary biologist Ernst Mayr defined a *species* as a reproductive community of populations (reproductively isolated from others) that occupies a specific niche in nature. In other words, species are defined by their genetic integrity because they share DNA with each other and not with other species.

There are difficulties with the definition of species. For example, a mule is the offspring of two distinct species, a donkey and a horse. How, then, does one classify a mule? Because mules are sterile and cannot reproduce, they are considered to be hybrids, not a species. Other examples of hybrids are Galapagos finches that interbreed, but whose offspring are sterile.

Some species show such a wide range of phenotypic variations that it is not initially obvious they all share a common gene pool. Dogs (*Canis familiaris*) come in a great variety of shapes and sizes. It may be difficult to believe that the Chihuahua and Great Dane are members of the same species. The breeding plumage of male birds often differs significantly from that of females and juveniles within a species.

Occasionally, non-interbreeding subpopulations exist within a species. Several subspecies of deer mice (*Peromyscus maniculatus*) are present in North America. Deer mice are best known as carriers of hantavirus. One subspecies, *Peromyscus maniculatus bairdii*, prefers open areas such as plowed or cultivated fields and grasslands, while *Peromyscus maniculatus gracilis* is found in forests. In addition to occupying different habitats, the mice differ in appearance. While the two subspecies may occupy the same area, they do not interbreed. They will, however, interbreed with other subspecies of deer mice.

Appendix 4.2A: Peer Assessment (Teacher Background)

Peer assessment involves students in assessing each other's work. Along with self-assessment, peer assessment is a component of assessment *as* learning, emphasizing student growth and self-understanding (metacognition). By engaging students as partners in the formative assessment process, peer assessment provides students the opportunity to practise and receive feedback without being graded on their work. Students gain a sense of ownership in the assessment process, thereby improving their motivation for learning.

When students discuss each other's work and make suggestions for improvement, they think analytically. This analytical thinking can be extended to their thinking about their own work, promoting self-reflection and self-assessment. Students develop the skills and habits of mind to take increasing responsibility for their own learning, and develop as independent, self-directed learners. They learn to recognize the characteristics of quality work.

In order for peer assessment to be used effectively in the classroom, certain prerequisites must be met.

1. Students must have a strong grasp of what they are to look for in their peer's work. Exemplars of strong and weak work can help students understand the assessment criteria and how to perform well. Engaging students in developing the assessment criteria also serves to extend their knowledge of the expectations concerning their work.

2. Peer assessment must be structured so that students understand they are to rate the work, not the student. By modelling effective descriptive feedback, teachers can help students formulate constructive feedback that is not judgmental. Students should be encouraged to be consistent, realistic, positive, and reflective when providing feedback to one another.

3. The learning environment in the classroom must be supportive. Students must feel comfortable and trust one another in order to provide honest and constructive feedback. By treating assessment as part of learning, students will come to view mistakes as opportunities for learning, rather than failures.

Peer assessment is a valuable means of formative assessment, as it allows students to ask each other questions they may be reluctant to ask their teacher, and explain things to each other using familiar language. Students see each other as resources for understanding when they have the opportunity to discuss new information, challenge ideas, and share explanations with each other. By supporting and scaffolding each other's learning, students can achieve beyond what they can learn on their own.

Appendix 4.2B: Guidelines for Peer Assessment (BLM)

When assessing the work of a peer, consider the following guidelines:

1. Focus on the work and process.
   - Give process-focused comments that suggest how to move the work closer to the target (e.g., Have you checked the Citation and Documentation handout for examples of the format to use for your reference page?).
   - General praise (e.g., Good work!) or personal comments (e.g., I like it!) are not helpful.

2. Provide non-judgmental, descriptive feedback.
   - Always talk about the work, not the person (e.g., I noticed that some boxes in the Concept Overview Frame have not been completed, NOT You didn't finish the Concept Overview Frame.).
   - Don't make judgments or evaluative statements about the work (e.g., This work is a failure.).

3. Be positive and make specific suggestions.
   - Describe how the strengths in a student's work match the criteria for good work (e.g., The conclusion in this lab report is stated clearly).
   - Describe what is missing or could be done better. Use a tone that shows you are making helpful suggestions (e.g., I'm not sure I understand your reasoning in this genetics problem. Could you explain it in another way?).

Examples of Feedback Prompts

- I am confused about the answer to this question. Can you explain your reasoning another way?
- Can you describe the strategy that you used to solve this problem?
- Have you checked your calculations in this question? Does $(0.2)^2 = 0.4$?
- I noticed you left some questions unanswered in the case study. Is there anything I can help you with?
- Your lab report is clear and organized. Have you checked your spelling and grammar?
- Your decision regarding the ethical dilemma is clear. What were the criteria you used to make this decision?
- Could you explain to me how you came to this conclusion based on the data you collected?

Appendix 4.3: The Changing Nature of Classification (Teacher Background)

The dynamic nature of classification is an excellent example of how the use of new and improved technologies have led to changes in the entire system of classification.

- Aristotle (384–322 BCE) created the first widely used classification system by dividing all organisms into two groups: plants and animals.
- Carolus Linnaeus (1707–1778) developed the hierarchical categorization system (kingdom, phylum, class, order, family, genus, species), and grouped organisms based on their resemblance to other life forms. The binomial nomenclature system developed by Linnaeus is still in use today.
- Improvements in light microscopes led to the discovery of a great number of single-celled organisms. Ernst Haeckel suggested in 1866 that these organisms be placed in a separate kingdom called *Protista*.
- The invention of the electron microscope and advances in biochemistry in the mid-1900s led to the discovery of the two different types of cells: the prokaryotes (bacteria) and the eukaryotes (plants, animals, fungi, and protists).
- Robert Whittaker proposed the five-kingdom system in 1959. Plants, animals, fungi, bacteria, and protists were placed in separate kingdoms: Plantae, Animalia, Fungi, Monera, and Protista.
- Carl Woese's analysis of the base sequence of ribosomal RNA in various bacteria in the 1970s led Woese to suggest that bacteria be subdivided into two distinct groups: the Eubacteria and Archaebacteria.
- Based on Woese's research, a six-kingdom system was suggested. The plant, animal, fungi, and protist kingdoms remained, while the bacteria kingdom was separated into the Eubacteria and Archaebacteria kingdoms. In 1990, Woese proposed the three-domain scheme of classification consisting of the following domains:
  - Eukarya (all eukaryotes including animals, plants, fungi, and protists)
  - Bacteria ("true" bacteria such as *E. coli, Lactobacillus bulgaris*, and *Cyanobacteria*)
  - Archaea (organisms that live in extreme environments such as high temperature or extreme salinity, or produce methane gas)

Appendix 4.4: Species and Systematics—Demonstration (Teacher Background)

Bring varieties of *Brassica oleracea* and other vegetables to the class, such as the following:

- cabbage (*Brassica oleracea capitata*)
- kale (*Brassica oleracea acephala*)
- broccoli, cauliflower, broccoflower (*Brassica oleracea botrytis*)
- Brussels sprouts (*Brassica oleracea gemmifera*)
- kohlrabi (*Brassica oleracea caulo-rapa*)
- turnip (*Brassica rapa*)
- bok choy (*Brassica chinensis*)
- iceberg lettuce (*Lactuca sativa*)

Show students the vegetables and ask them to categorize the vegetables into genus and species. Students will likely group species according to look-alikes (e.g., iceberg lettuce and cabbage).

When students have made their arrangement, show them the actual groupings and their genus and species names. Note that obvious morphological traits are not always important in defining species. In this case, the detail of the flowers present is used to define the *Brassica* genus, and the arrangement of stalks defines the *Brassica* species.

The varieties of *Brassica oleracea* are all artificially selected and derived from the wild type that grows on the sea cliffs of Europe. The number of *Brassica oleracea* varieties is a representation of the genetic variation in a species. Artificial selection can be demonstrated with broccoli, cauliflower, and broccoflower (*Brassica oleracea botrytis*), which have been bred for selected traits. Remind students of the role that artificially bred plants and animals played in the development of Charles Darwin's ideas on natural selection.

Discuss the system of binomial nomenclature for naming species, developed by Carl Linnaeus and still in use today. These samples effectively reinforce the idea that the scientific names do mean something (if you know Latin and Greek).

- *brassica* = cabbage
- *acephala* = no head
- *capitata* = head botrytis = bunch of grapes
- *oler* = greens
- *caulo* = turnip
- *rapa* = stem
- *gemmifera* = bud-bearing
- *chinensis* = Chinese
- *lactuca* = lettuce

Appendix 4.5: Categorical Reasoning in Biology (BLM)

Introduction

Something that is true about a group or a category will be true for every member of that group or category. For example, you know that all birds are vertebrates. You also know that a robin is a type of bird. Therefore, you could reason that a robin is a vertebrate.

This type of reasoning is known as *categorical reasoning*. Categorical logic is the basis for classification systems. It examines relationships according to groups or categories of things. The argument can be set up formally as follows:

Premise: All birds are vertebrates.

Given: A robin is a bird.

Conclusion: A robin is a vertebrate.

Questions

1. Using the example above as a model, construct a categorical argument to show that a Labrador retriever is a mammal.
2. Explain the thought processes you used in answering question 1.
3. Construct a categorical argument to show that a pine tree is a plant.
4. Is the categorical logic below correct? Explain your thinking.

   Premise: All horses are herbivores.

   Given: Organism X is a herbivore.

   Conclusion: Organism X is a horse.

Appendix 4.6:
The Three Domains of Life (Teacher Background)

In 1990, Carl Woese proposed the following three-domain scheme of classification:

- **Domain Eukaraya** (all eukaryotes, including animals, plants, fungi, and protists). Members of this domain are composed of eukaryotic cells that contain nuclei and membrane-enclosed organelles such as mitochondria and chloroplasts.
- **Domain Bacteria/Eubacteria** ("true" bacteria such as *Escherichia coli, Lactobacillus bulgaris*, and *Nostoc* spp.). Members of this domain are composed of prokaryotic cells, but they are biochemically and genetically distinct from the Archaea in that their cell walls contain the protein peptidoglycan.
- **Domain Archaea** (organisms such as *Acidianus* spp., *Halobacterium* spp., and *Methanobacterium* spp. that live in extreme environments). Members of this domain are composed of prokaryotic cells, but they are biochemically and genetically distinct from the Bacteria in that their RNA contains distinct sequences. In fact, Archaea are probably more closely related to humans than they are to Bacteria.

Current research uses molecular genetics and DNA/RNA sequencing to determine evolutionary relationships. Rapid gains in knowledge are leading to a reclassification of organisms, particularly the Protista kingdom. This group contains a diverse group of single-celled organisms that do not fit in the Plantae, Animalia, or Fungi kingdoms. This group is organized into several distinct kingdoms such as Chromista (e.g., diatoms, kelp), Rhodophyta (e.g., red algae), and Myxomycophyta (e.g., slime moulds).

New names are coming into to use for kingdoms Animalia and Plantae. Some sources are using Metazoa (animals) and Chlorobionta (plants) to reflect the changes in classification based on phylogenetics.

UNIT 5: CONSERVATION OF BIODIVERSITY

Unit 5: Conservation of Biodiversity

Specific Learning Outcomes

B12-5-01: Discuss a variety of reasons for maintaining biodiversity. (GLOs: B2, B5, D2)

Include: maintaining a diverse gene pool, economic value, and sustainability of an ecosystem

B12-5-02: Describe strategies used to conserve biodiversity. (GLOs: B2, B5, D2)

Examples: habitat preservation, wildlife corridors, species preservation programs, public education . . .

B12-5-03: Select and use appropriate tools or procedures to determine and monitor biodiversity in an area. (GLOs: C1, C2, C7)

Examples: field guides, dichotomous keys, quadrats, transects, mark and recapture . . .

B12-5-04: Investigate an issue related to the conservation of biodiversity. (GLOs: C4, C6, C8, D2, E2)

Examples: heritage seeds, water quality in Lake Winnipeg, land-use designations, hydroelectric development . . .

MAINTAINING BIODIVERSITY

SPECIFIC LEARNING OUTCOME

B12-5-01: Discuss a variety of reasons for maintaining biodiversity. (GLOs: B2, B5, D2)

Include: maintaining a diverse gene pool, economic value, and sustainability of an ecosystem

SLO: B12-5-01

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 6 Science, students were introduced to the concept of biodiversity and they observed and described the variety of living things in their local environment.

Students identified environmental, social, and economic factors that should be considered in the management and preservation of ecosystems in Grade 7 Science.

In Grade 10 Science, students examined the complex relationships present in ecosystems and explained how the biodiversity of an ecosystem contributes to its sustainability. They investigated how human activities affect an ecosystem and used the decision-making model to propose a course of action to enhance its sustainability.

TEACHER NOTE

Values clarification is an effective way for students to reflect on what their values are, why they value certain things, and how they can look beyond themselves into the worlds around them. You may first wish to discuss the definition of *value*. The teacher's role in the learning activities is that of a facilitator who does not impose his or her own values on the discussion.

When discussing an environmental issue, it is important to present more than just the conservationist side (i.e., save the planet). Students need to realize that there is not just one "right" answer to a problem, and that decisions are often based on priorities. What is one person's priority may not be that of another. This difference in priorities can lead to conflict.

BACKGROUND INFORMATION

This learning outcome provides the opportunity to integrate cultural/local and community perspectives/values into the discussion of biodiversity. Students should understand that values may vary from one group to another. For example, sweetgrass (*Hierochloe odorata*) is of great sacred (inherent) value to First Nations peoples. The smoke of burning sweetgrass is used to purify and cleanse objects, places, and people. Sweetgrass is also of utilitarian value in that it can be used to keep clothing fresh when stored. It has also been used to make baskets. Tea made from its leaves has been used to treat fever, coughs, and sore throats.

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5: Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

Resource Links

- Canadian Water Resources Association (CWRA). *Project WET.* <www.cwra.org/branches/ProjectWet/>.

  This is an interdisciplinary water-based environmental and conservation education program for elementary and secondary school educators. Project WET curriculum and activity guides are supplied to all who attend workshops.

- Canadian Wildlife Federation (CWF). "Wild Education." *CWF Education.* <www.cwf-fcf.org/en/educate/ed_resources/for-educators/>.

  This website provides elementary and secondary school educators with conservation education programs such as Project WILD, Fish Ways, and Below Zero. Activity guides are supplied to all who attend WILD workshops.

MAINTAINING BIODIVERSITY

SPECIFIC LEARNING OUTCOME

B12-5-01: Discuss a variety of reasons for maintaining biodiversity. (GLOs: B2, B5, D2)

Include: maintaining a diverse gene pool, economic value, and sustainability of an ecosystem

ACTIVATE

KWL Chart

To activate students' prior knowledge, use the KWL (know, want to know, learned) strategy (Ogle). Provide students with a KWL Chart at the start of the unit and ask them to fill in the What I Know and What I Want to Learn columns. See Appendix 5.1: Conserving Biodiversity—KWL Chart (BLM). At the end of the unit, ask students to return to their KWL Charts and complete the What I Learned column.

Utilitarian and Inherent Value—Think-Pair-Share

Have students, individually, think of and list items they use in their everyday lives that come from natural sources. Students then find a partner and share their lists. Lists may include items such as leather shoes, milk, vegetables, vitamins, gasoline, and so on.

Ask the pairs to think of and record a list of things they appreciate in nature. Lists may include items such as bird songs, flowers, sunsets, clean air, walking on a beach or in a forest, and so on.

Pose the following question to the groups:

- How would you describe the difference between the two lists?

Students' responses should indicate that the first list contains items we consider to be useful or practical (utilitarian), while the second list contains items of intrinsic or natural beauty (inherent).

ACQUIRE/APPLY

Maintaining Biodiversity—Class Discussion (U1)

Discuss with students the terms *utilitarian* (useful, practical) and *inherent* (intrinsic, natural) and provide definitions. Based on the definitions and the Think-Pair-Share learning activity, students list examples of items of personal utilitarian value (e.g., cow—leather and food) and personal inherent value (e.g., robin's song—cheerful sound).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5: Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

Suggestion for Assessment

Scan the lists to assess students' understanding of the meaning of utilitarian and inherent value. The information gathered can be used to plan further instruction (formative assessment).

Values Clarification (U2, P3, P4, D3, D4, G2)

This learning activity will introduce students to values clarification and assist them with determining how they value biodiversity. See Appendix 5.2: Values Clarification (BLM) for the student handout.

MAINTAINING BIODIVERSITY

SPECIFIC LEARNING OUTCOME

B12-5-01: Discuss a variety of reasons for maintaining biodiversity. (GLOs: B2, B5, D2)

Include: maintaining a diverse gene pool, economic value, and sustainability of an ecosystem

Suggestion for Assessment

Use the discussion and written responses from the Values Clarification learning activity to assess whether students can

- identify potential conflicts that may arise when making decisions on environmental issues
- explain the logic and validity involved in forming personal opinions

Group work skills can be assessed with a checklist. See Appendix 1.13: Collaborative Process—Assessment (BLM).

Preserving Biodiversity—Demonstrating Understanding (U1)

Pose the following questions to students at the end of the class:

> Should we preserve only those things in nature that have utilitarian value? Why or why not?

Give students five minutes to respond in their notebooks.

Suggestion for Assessment

This learning activity provides a quick formative assessment of what students learned in a particular lesson. Assess students' responses, checking for logic and clarity in the following areas:

- the students' position on the issue
- the rationale explaining the position

Envirothon (U2, P1, P2, G1)

Envirothon is a hands-on environmental problem-solving competition for high school students. Participating teams complete training and testing in five natural resource categories:

- soils and land use
- aquatic ecology
- forestry
- wildlife
- current environmental issues

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5: Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

Resource Links

- Canon Envirothon. Home Page. <www.envirothon.org/>.

  This is an annual competition in which the winning state/provincial teams compete for recognition and scholarships by demonstrating their knowledge of environmental science and natural resource management.

- Manitoba Forestry Association. "Manitoba Envirothon." *ThinkTrees*. <www.thinktrees.org/Envirothon.aspx>.

  Visit this website for information on the Manitoba Envirothon.

MAINTAINING BIODIVERSITY

SPECIFIC LEARNING OUTCOME

B12-5-01: Discuss a variety of reasons for maintaining biodiversity. (GLOs: B2, B5, D2)

Include: maintaining a diverse gene pool, economic value, and sustainability of an ecosystem

Suggestion for Assessment

Have students complete an "I Used to Think, But Now I Know" reflection after participating in the Envirothon. Ask students to recall their ideas about current environmental issues prior to the competition, and have them explain how their ideas changed or became more detailed as a result of their participation (Keeley). Students can discuss their reflections with a partner.

Riparian Zone Assessment—Culminating Task (U2, S1, D1, D2, D3, D4, D5, I1, I4)

The Riparian Zone Assessment task is designed to integrate the four Conservation of Biodiversity learning outcomes and a number of skills and attitudes outcomes into one major assignment. Refer to Appendix 5.3A: Riparian Zone Assessment (Teacher Background) and Appendix 5.3B: Riparian Zone Assessment (BLM). This task can be done in one class, or it can be expanded to several classes, depending on the amount of fieldwork incorporated or the number of case studies examined. A general conservation dilemma (e.g., the clearing of riparian zones for beach property) or a local riparian issue (e.g., local stream/riverbank erosion or development) could be presented.

Suggestions for Assessment

Have students prepare a scientific report incorporating technical writing to address a local riparian issue they have investigated. The report should

- identify the issue and its parameters
- describe possible courses of action and resulting consequences
- make a recommendation that is the most ecologically sustainable

For more information about the decision-making process, refer to Appendix 1.12: Decision Making (Teacher Background). Fieldwork and group work skills can be assessed with checklists. See Appendix 5.4A: Fieldwork Skills Checklist—General Skills (BLM), Appendix 5.4B: Fieldwork Skills Checklist—Thinking Skills (BLM), and Appendix 1.13: Collaborative Process—Assessment (BLM).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5: Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

Create an assessment rubric for the report by developing the assessment criteria and performance levels in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. Alternatively, provide students with exemplars of strong and weak reports, and have them work in groups to identify possible assessment criteria and define levels of performance. The exemplars can be anonymous samples of student work done in previous years.

CONSERVATION STRATEGIES

SPECIFIC LEARNING OUTCOME

B12-5-02: Describe strategies used to conserve biodiversity. (GLOs: B2, B5, D2)

Examples: habitat preservation, wildlife corridors, species preservation programs, public education . . .

SLO: B12-5-02

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 7 Science, students identified environmental, social, and economic factors that should be considered in the management and preservation of ecosystems. Students proposed a course of action to protect the habitat of a particular organism within an ecosystem. In Grade 9 Science, students investigated how human activities affect an ecosystem and used the decision-making model to propose a course of action to enhance its sustainability.

TEACHER NOTE

Various biodiversity conservation strategies are in use in Manitoba. Some programs focus on the conservation of a particular species, while others focus on preserving or restoring a habitat in order to conserve the biodiversity of the ecosystem. A local or regional focus on the conservation of Manitoba's biodiversity is recommended.

BACKGROUND INFORMATION

Students often confuse conservation with preservation. Clarify the concepts, indicating that *conservation* focuses on maintaining species biodiversity through sustainable management of wild plants and animals and their habitats. Indicate that management does not necessarily mean a "no-kill" policy. For example, the deer population of Manitoba is managed in part through hunting. A species *preservation* program generally concentrates on protecting a particular endangered plant or animal from extinction (e.g., captive breeding programs in zoos).

The term *stewardship* refers to the wide range of voluntary actions that we can take to care for the environment. Activities range from monitoring and conserving wildlife species and their habitat to protecting and improving the quality of soil, water, air, and other natural resources.

ACTIVATE

Habitat Conservation/Species Preservation Programs—Brainstorming

Students will have some familiarity with a variety of conservation/preservation programs. Lead a class brainstorming session on habitat conservation/species preservation programs and record suggestions generated by students.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Examples of habitat conservation/species preservation programs:

- seed banks
- zoos
- captive breeding programs
- adopt an animal (e.g., World Wildlife Fund program)
- species recovery (e.g., bison in the Chitek Lake area of Manitoba)
- habitat protection (e.g., developing parks and preserves)
- prevention of illegal trade of wildlife (e.g., bear gallbladders, rare orchids)
- habitat restoration (e.g., restoring wetlands, removing toxic waste)
- public education (e.g., identifying species at risk)
- wildlife corridors
- forest management
- bag/creel limits for hunters, fishers, and trappers

CONSERVATION STRATEGIES

SPECIFIC LEARNING OUTCOME

B12-5-02: Describe strategies used to conserve biodiversity. (GLOs: B2, B5, D2)

Examples: habitat preservation, wildlife corridors, species preservation programs, public education . . .

ACQUIRE/APPLY

Habitat Conservation/Species Preservation Programs—Class Discussion (U2, P3, P4)

Using the list of habitat conservation/species preservation programs generated by the class, differentiate between habitat conservation and species preservation. Have students review the list of programs and identify which programs focus on habitat conservation and which focus on species preservation. Students could create Venn diagrams, placing habitat conservation programs (e.g., habitat restoration, forest management) on one side of the diagram, species preservation programs (e.g., zoos, bag limits) on the other side of the diagram, and programs that do both (e.g., public education) in the overlapping part of the diagram.

Suggestion for Assessment

Venn diagrams can be assessed by the teacher to monitor students' understanding (formative assessment), or shared and discussed with other students/groups (peer assessment). For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

Strategies for Conserving Biodiversity—Class Discussion (U1, P2, P3)

Discuss strategies used to conserve biodiversity. A wealth of information can be found in a variety of multimedia formats.

Resource Links

- Assiniboine Park Zoo. "Conservation Corner." *Programs: Education and Experience.* <www.zoosociety.com/programs/conservation-corner.php>.

  The Zoo's Education Centre promotes the concept of endangered species and wildlife conservation through education and interactive learning. Refer to this website for links related to environmentalism, conservation, and zoos. To book group programs, seasonal camps, and guided tours, call the Park Programming Office at 204-927-6070 or email <parkprograms@assiniboinepark.ca>.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

- Canadian Wildlife Federation (CWF). Home Page. <www.cwf-fcf.org/>.
  CWF advocates for the protection of Canada's wild species and spaces and is dedicated to fostering awareness and enjoyment of our natural world. This website contains information on programs, resources, current issues, and actions, and has links to other websites.

- Environment Canada. "Education and Awareness." Canadian Biodiversity Information Network (CBIN). <www.cbin.ec.gc.ca/education/>.
  CBIN promotes awareness of biodiversity. This website provides educators with links to interactive resources such as *Hinterland Who's Who* and the Museum of Nature.

- ———. *EnviroZine.* <www.ec.gc.ca/envirozine/>.
  This online news magazine addresses a wide range of environmental issues of interest to Canadians.

CONSERVATION STRATEGIES

SPECIFIC LEARNING OUTCOME

B12-5-02: Describe strategies used to conserve biodiversity. (GLOs: B2, B5, D2)

Examples: habitat preservation, wildlife corridors, species preservation programs, public education . . .

- Manitoba Conservation. Home Page. <www.gov.mb.ca/conservation/>.
  This provincial website contains information on sustainable resource management, Manitoba species at risk, wildlife protection, the protected areas initiative, and other topics.
- NatureNorth.com. Home Page. <www.naturenorth.com/>.
  Manitoba's online nature magazine is dedicated to celebrating Manitoba's biodiversity.
- World Wildlife Fund (WWF)—Canada. Home Page. <www.wwf.ca/>.
  WWF is dedicated to conserving the world's biological diversity, ensuring that the use of renewable resources is conducted in a sustainable manner, and promoting the reduction of pollution and wasteful consumption. This website contains information on conservation programs and resources, and has links to other websites.

Suggestion for Assessment

During the last five minutes of the class, have students complete an Exit Slip, reflecting on questions such as the following:

- What do you know now that you didn't know before class today?
- What did you already know?
- What questions do you still have?

Review students' responses, looking for areas of confusion, and address the questions during the next class (formative assessment). For information on Exit Slips, see *SYSTH* (p. 13.9).

Skills and Attitudes Outcomes

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Biodiversity Conservation Strategies—Guest Speaker (P2, P3, I1)

Invite a speaker to discuss biodiversity conservation strategies with the class. Speakers could include the following:

- conservation officer
- Elder
- National Park Warden Association representative
- Conservation District manager
- Manitoba Wildlife Federation representative
- Canadian National Trappers Alliance member

Students should prepare questions for the guest speaker in advance of the visit. This is a good opportunity for students to explore related careers.

CONSERVATION STRATEGIES

SPECIFIC LEARNING OUTCOME

B12-5-02: Describe strategies used to conserve biodiversity. (GLOs: B2, B5, D2)

Examples: habitat preservation, wildlife corridors, species preservation programs, public education . . .

Suggestion for Assessment

Have students summarize highlights of the guest speaker's presentation in their notebooks. Summaries can then be shared with classmates and peer assessed for content. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

Species Preservation or Habitat Conservation—Public Awareness Campaign and Presentation (U2, P3, I2, I3, I4)

Students individually select and research a species preservation or habitat conservation program and design a campaign to promote public awareness of the issue. The campaigns should include information on the type of program, the characteristics of the program, and the source of funding. They present their work in a format of their choice.

Suggestions for Assessment

Students prepare and present their public awareness campaigns. Campaigns can be presented in a variety of formats:

- multimedia presentation (e.g., PowerPoint, wiki, podcast, website)
- oral presentation
- written report (e.g., pamphlet, brochure)
- visual display (e.g., poster, bulletin board)

Presentation components may vary, depending on the type of presentation. Refer to Appendix 5.8: Checklist for Creating Visuals (BLM) for use with visuals (e.g., posters, collages, graphic organizers) and Appendix 5.9: Oral Presentation—Observation Checklist (BLM).

Develop assessment criteria for the public awareness campaign presentation in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. The assessment criteria should include both content and presentation components. The content criteria should include the use of key terms and understandings from the unit.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Alternatively, provide students with exemplars of effective and ineffective public awareness campaigns. Students can then work in groups to identify assessment criteria and levels of performance for a rubric. The exemplars can be teacher-generated or anonymous samples of student work done in previous years.

Take a Stand—Decision Making (U2, D1, D3, D4)

This learning activity encourages open-mindedness and demonstrates the range of possible views on a controversial topic. It enables students to explore the grey areas that lie between the polar opposites of an issue, and helps them develop an appreciation for the spectrum of possible views. Refer to Appendix 5.5A: Take a Stand (Teacher Background) for information on using the learning activity with your class. For decision-making issues, see Appendix 5.5B: Take a Stand—Scenarios.

CONSERVATION STRATEGIES

SPECIFIC LEARNING OUTCOME

B12-5-02: Describe strategies used to conserve biodiversity. (GLOs: B2, B5, D2)

Examples: habitat preservation, wildlife corridors, species preservation programs, public education . . .

Suggestion for Assessment

Students individually reflect on their participation in the Take a Stand learning activity and describe the values (utilitarian and/or inherent) they used in determining their decision. The reflection should

- describe the initial position the student took on the issue
- identify the values used in determining his or her position
- indicate whether or not his or her position on the issue changed during the learning activity
- explain why his or her position changed or did not change

Assess students' responses for accuracy and clarity.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

NOTES

MONITORING BIODIVERSITY

SPECIFIC LEARNING OUTCOME

B12-5-03: Select and use appropriate tools or procedures to determine and monitor biodiversity in an area. (GLOs: C1, C2, C7)

Examples: field guides, dichotomous keys, quadrats, transects, mark and recapture . . .

SLO: B12-5-03

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 6 Science, students identified living things using an existing classification key, and they observed and described the diversity of living things in the local environment. In Grade 10 Science, students observed and documented a range of organisms that illustrate the biodiversity within a local or regional ecosystem. Statistical sampling procedures are introduced in Grade 11 Applied Mathematics.

TEACHER NOTE

This learning outcome provides an opportunity to incorporate fieldwork into the unit. However, if the weather or resources do not permit fieldwork, various sampling methods can be simulated. Refer to Appendix 5.6A: Investigating Population Size (BLM) and Appendix 5.6B: Investigating Population Size (Answer Key).

BACKGROUND INFORMATION

Field guides and *dichotomous keys* are tools used to identify organisms in the field. Plant populations can be sampled with *transects* or *quadrats*, which are plots within which the number or type of species is counted in randomly selected areas. The size of a mobile animal population can be estimated using the *mark and recapture* technique in which the organism of study is tagged or banded.

These techniques are based on random sampling statistical procedures. Care must be taken to assure that randomness occurs when the sampling is performed; otherwise, erroneous population estimates will result. Biologists can then determine whether a population is growing or declining by repeating sampling procedures over time.

ACTIVATE

Turn to Your Neighbour

Pose the following question to students:

- How do biologists working in the field identify the different species of organisms they find?

Students turn to their neighbours to discuss their ideas.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Students' responses may include the following:

- field guides
- reference books
- dichotomous keys
- knowledge of experts
- personal knowledge
- knowledge of Elders

ACQUIRE/APPLY

Using a Dichotomous Key/Field Guide—Samples and Demonstration (U2)

Provide students with samples of dichotomous keys and field guides and demonstrate their use. Dichotomous keys are readily available in textbooks, in lab manuals, and on the Internet.

MONITORING BIODIVERSITY

SPECIFIC LEARNING OUTCOME

B12-5-03: Select and use appropriate tools or procedures to determine and monitor biodiversity in an area. (GLOs: C1, C2, C7)

Examples: field guides, dichotomous keys, quadrats, transects, mark and recapture . . .

Resource Links

Sources of field guides and keys for local flora and fauna are suggested below.

- Lone Pine Publishing. Home Page. <www.lonepinepublishing.com/>.

  This publisher produces books focusing on local wildlife, history, and the outdoors. Field guides include the following:
  - *Animal Tracks of Manitoba* (Sheldon and Eder)
  - *Manitoba Birds* (Bezener and De Smet)
  - *Manitoba Wayside Wildflowers* (Kershaw)
  - *Saskatchewan and Manitoba Nature Guide* (Kagume)
  - *Reptiles and Amphibians of Canada* (Fisher and Brooks)

- Manitoba Conservation. *Field Guide: Native Trees of Manitoba*. Winnipeg, MB: Manitoba Conservation, n.d. Available online at <www.gov.mb.ca/conservation/forestry/pdf/health/fieldguidefinal.pdf>.

  This field guide, available on the Forestry Branch website, explains how to identify native Manitoba trees using leaves and twigs.

- ———. *Key to Manitoba's Sport Fish*. Winnipeg, MB: Manitoba Conservation, n.d. Available on the Manitoba Water Stewardship website at <www.gov.mb.ca/waterstewardship/fisheries/education/fishkey1.pdf>.

  This document has a dichotomous key to Manitoba's sport fish.

Suggestion for Assessment

Students use a dichotomous key or a field guide to identify organisms. The responses can be used as formative assessment to determine students' levels of understanding and to guide further teaching/learning activity selection (if needed).

Building Vocabulary (U1)

Introduce new vocabulary to students as required. The use of a variety of strategies (e.g., Three-Point Approach, Sort and Predict, Word Clusters) can aid students in developing both conceptual and contextual knowledge of the vocabulary of monitoring biodiversity. Refer to *SYSTH* (Chapter 10) for more information on building a scientific vocabulary and for think-sheet frames.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Suggestion for Assessment

Review students' think-sheet frames to ensure accuracy. As this learning activity is intended as a formative assessment to check student understanding, no mark is required.

Ecological Field Studies—Field Work/Trip (U2, P2, S2, S5)

A variety of organizations across Manitoba offer programs that provide students with the opportunity to engage in ecological field studies. This is also a good opportunity for students to explore related careers.

Resource Links

- FortWhyte Alive. Home Page. <www.fortwhyte.org/>.

  The Fort Whyte Centre in Winnipeg offers a variety of hands-on field research programs for high school students. For more information, visit the website or call the centre at 989-8364.

- Manitoba Conservation. "Teacher's Corner." *Educational Opportunities.* <www.gov.mb.ca/conservation/parks/education/teachers.html>.

  The Parks and Natural Areas Branch of Manitoba Conservation offers free-of-charge school programs in some provincial parks across Manitoba.

MONITORING BIODIVERSITY

SPECIFIC LEARNING OUTCOME

B12-5-03: Select and use appropriate tools or procedures to determine and monitor biodiversity in an area. (GLOs: C1, C2, C7)

Examples: field guides, dichotomous keys, quadrats, transects, mark and recapture . . .

- Oak Hammock Marsh. <www.oakhammockmarsh.ca/>.
  This interpretive centre is open year-round and offers a variety of curriculum-based programs for students. For more information, visit this website or call 1-888-506-2774 (toll-free).

Suggestions for Assessment

Have students complete an assignment based on their fieldwork. Alternatively, have students complete an I Used to Think, But Now I Know reflection after the field trip. Ask them to recall their ideas at the start of the topic study, and have them explain how their ideas changed or became more detailed compared to what they knew at the beginning of instruction (Keeley). Students can discuss their reflections with a partner.

Fieldwork and group work skills can be assessed with checklists. See Appendix 5.4A: Fieldwork Skills Checklist—General Skills (BLM), Appendix 5.4B: Fieldwork Skills Checklist—Thinking Skills (BLM), and Appendix 1.13: Collaborative Process—Assessment (BLM).

Estimating Population Size—Investigation (U2, P1, S3, S4, I4)

Refer to Appendix 5.6: Investigating Population Size (BLM) for an investigation that introduces students to quadrat and transect sampling, as well as the mark and recapture method. **Note:** Use 800 to 1000 grains of rice per jar when preparing the jars for the mark and recapture exercise in the investigation.

Suggestion for Assessment

Assessment of this investigation can be summative (written responses to the questions posed) or formative. The RERUN strategy (Keeley 172–73) can be used for formative assessment of student learning in place of a formal summative lab report.

After students have completed the investigation and answered questions about it, ask them to reflect on their lab experience (individually or in groups) by writing a sentence or two for each letter of the acronym, **RERUN**: **R**ecall (what you did), **E**xplain (why you did it), **R**esults (what you found out), **U**ncertainties (what remains unclear), and **N**ew (what you learned).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

NOTES

INVESTIGATING A CONSERVATION ISSUE

SPECIFIC LEARNING OUTCOME

B12-5-04: Investigate an issue related to the conservation of biodiversity. (GLOs: C4, C6, C8, D2, E2)

Examples: heritage seeds, water quality in Lake Winnipeg, land-use designations, hydroelectric development . . .

SLO: B12-5-04

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 7 Science, students identified and described positive and negative examples of human interventions that have an impact on ecosystems. They identified environmental, social, and economic factors that should be considered in the management and preservation of ecosystems.

In Grade 10 Science, students explained how the biodiversity of an ecosystem contributes to its sustainability. They investigated how human activities affect an ecosystem and used the decision-making model to propose a course of action to enhance its sustainability.

BACKGROUND INFORMATION

A range of issues relate to the conservation of biodiversity in Manitoba. A local or regional focus is recommended. The issue of water quality, particularly in Lake Winnipeg, is an ongoing concern. Newspaper articles are readily available on the topic. A variety of topics related to agriculture could be examined, including the grazing of livestock in riparian zones, draining of potholes, and maintenance and planting of shelterbelts. The impact of logging in the boreal forest is another possible area of discussion.

ACTIVATE

Brainstorming

Pose the following question to students:

- A number of issues related to the conservation of biodiversity are being discussed in Manitoba today. Which issues, if any, are you aware of?

Lead a class brainstorming session on current issues related the conservation of biodiversity in Manitoba and record the suggestions generated by students. Students' responses could include the following:

- polar bears in Churchill threatened by climate change
- logging in the boreal forest
- invasive species (e.g., purple loosestrife, zebra mussels, rusty crayfish)
- decline of Lake Winnipeg

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5: Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

- at-risk species (e.g., sturgeon, piping plover, peregrine falcon, burrowing owl)
- possible introduction of foreign species through diversion of water from Devil's Lake, North Dakota, into the Red River
- shelterbelts in agricultural areas

The resulting list can be used by students to select a current issue to investigate related to the conservation of biodiversity in Manitoba (see Investigating a Local Conservation Issue—Decision Making, another learning activity suggested for learning outcome B12-5-04).

INVESTIGATING A CONSERVATION ISSUE

SPECIFIC LEARNING OUTCOME

B12-5-04: Investigate an issue related to the conservation of biodiversity. (GLOs: C4, C6, C8, D2, E2)

Examples: heritage seeds, water quality in Lake Winnipeg, land-use designations, hydroelectric development . . .

ACQUIRE/APPLY

Conserving Manitoba's Woodland Caribou (U2, P3, P4, D1)

The Manitoba Model Forest offers educational resources related to conserving Manitoba's woodland caribou.

Resource Links

- Manitoba Model Forest, Inc. Home Page. <www.manitobamodelforest.net/>.
- ———. *The Wonderful World of the Boreal Woodland Caribou*. <www.manitobamodelforest.net/publications/Wonderful%20World%20of%20the%20Boreal%20Woodland%20Caribou%20Curriculum.%20PDF.pdf>.

  This resource contains educational material on the life requisites of woodland caribou and their status as a threatened species, information on First Nations peoples' relationship to caribou, educational games, and a video.
- *Shadows of the Forest*. Prod. Eastern Region Woodland Caribou Advisory Committee. 2004. Video.

  This video tells the story of Manitoba's threatened caribou and the work being done to protect them. The 25-minute video introduces the woodland caribou and some of the factors that make it a species at risk. The second half of the video documents research activities, including state-of-the-art collaring and computer mapping that the Eastern Region Woodland Caribou Advisory Committee has undertaken to protect caribou habitat. Copies of this video are available in DVD or VHS format by contacting the Manitoba Model Forest office at 204-340-5013.

Conservation of Biodiversity—Case Study (U1, P4, D2, D3, I2)

Have students use case studies to investigate an issue related to the conservation of biodiversity.

Resource Link

- National Center for Case Study Teaching in Science, University at Buffalo. Home Page. <http://sciencecases.lib.buffalo.edu/cs/>.

  This website contains a variety of case studies, which teachers can modify or adapt for classroom use, subject to the specified usage guidelines. Teaching notes and answer keys for the case studies are available free of charge. To access the answer keys, users are required to register for a password.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5: Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Suggestion for Assessment

Assessment will depend on the type of learning activity undertaken. Whatever the form of assessment used, students should be made aware of the criteria beforehand.

INVESTIGATING A CONSERVATION ISSUE

SPECIFIC LEARNING OUTCOME

B12-5-04: Investigate an issue related to the conservation of biodiversity. (GLOs: C4, C6, C8, D2, E2)

Examples: heritage seeds, water quality in Lake Winnipeg, land-use designations, hydroelectric development . . .

Investigating a Local Conservation Issue—Decision Making (D1, D2, D4, D5, I3, I4)

Have students investigate a current issue related to the conservation of biodiversity in Manitoba. This investigation should include some type of decision-making process. The types of decisions can vary greatly. For example, they could include

- personal/individual decisions (e.g., Should I fill in a pothole on my land for additional farmland, or should I preserve it as a nesting site for birds?)
- community decisions (e.g., Should our community raise its tax rate to pay for an improved waste water treatment plant that would improve the water quality in Lake Winnipeg?)
- societal decisions (e.g., Should we continue to build hydroelectric dams in Manitoba, or should we explore other alternatives?)

A variety of approaches can be used to simulate a real-life context or to promote interactions among students. For more details, refer to Appendix 1.12: Decision Making (Teacher Background).

Suggestions for Assessment

Have students prepare a scientific report, incorporating technical writing, to address the Manitoba conservation issue they have investigated. The report should

- identify the issue and its parameters
- describe possible courses of action and resulting consequences
- make a recommendation that is the most ecologically sustainable

Create an assessment rubric for the report by developing the assessment criteria and performance levels in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. Alternatively, provide students with exemplars of strong and weak reports, and have them work in groups to identify possible assessment criteria and define levels of performance. The exemplars can be anonymous samples of student work done in previous years.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4: Recognize that humans have had and continue to have an impact on the environment. (GLOs: B1, B2)

B12-0-D1: Identify and explore a current issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2: Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3: Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5: Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

KWL Chart (U2)

Ask students to return to their KWL Charts (which they started at the beginning of this topic study) and complete the "What I learned" column. See learning outcome B12-5-01 and Appendix 5.1: Conserving Biodiversity—KWL Chart (BLM).

Suggestion for Assessment

After students have completed the What I Learned column in their KWL Charts, ask them to compare the three columns and self-assess and reflect on how their conceptual understanding of the conservation of biodiversity has progressed. The information from the KWL Charts can be used to identify whether further lessons are required (formative assessment).

NOTES

Unit 5: Conservation of Biodiversity

Appendices

Appendix 5.1:
Conserving Biodiversity—KWL Chart (BLM)

Name ______________________________

What I Know	**What I Want to Learn (state as questions)**	**What I Learned**
Reasons for maintaining biodiversity		
Strategies used to preserve biodiversity		
Methods used to determine and monitor biodiversity		

Appendix 5.2: Values Clarification (BLM)

Introduction

What do you value? What is important to you? Scientists, economists, and policy makers are attempting to determine how important biodiversity is to humans and how it is of value. In this learning activity, you will decide how you value biodiversity.

Procedure

Step 1

With a learning partner, discuss the following questions on how your life is affected by biological diversity.

a) Which would have a greater impact on your life—if all the bears in the world became extinct or if all the snails in the world became extinct?

b) Bacteria, fungi, and other micro-organisms are decomposers in ecosystems. What would happen if these organisms no longer existed on Earth?

Step 2

Answer the following questions individually, and then discuss your answers with your learning partner.

a) To build a shopping mall and a parking lot, a developer wants to build on a field that contains one of the few remaining stands of tall grass prairie in Manitoba. Would you be for or against this development? Explain your answer.

b) What if the land was to be developed as housing for low-income families and senior citizens? Would your answer be different? Why or why not?

c) If you won a lottery prize of $1 million, how much of the money would you give to save one hectare of endangered forest?

d) Was it hard for you to put a dollar value on the endangered forest? Why or why not?

Step 3

a) Rank the five species listed below in order of their value to you by arranging them on the continuum from high to low value.

Species: snail, fox, moss, tuna, rattlesnake

High Value **Low Value**

b) Now place the species with the highest value at the top of the list in the chart below. Then provide your rationale for your ranking.

Species	Reason for Ranking

Reason for Ranking Species

Suppose the organisms above were endangered and you had to save them from extinction. Which would you save, and why?

Reference

Blair, Robert. B. et al. *Ecology: Teacher's Guide*. Chicago, IL: Everyday Learning, 1999.

Appendix 5.3A: Riparian Zone Assessment (Teacher Background)

Introduction

> Riparian areas, especially those in prairie environments, support high levels of natural biodiversity. The combination of water, lush vegetation and connections to other landscapes provides opportunities for many species . . . . Riparian areas create important corridors that link a variety of ecosystems together. Species and genetic material travel easily through these small, but unique, pieces of the landscape. (Alberta Riparian Habitat Management Society, *Biodiversity and Riparian Areas 2*)

The Riparian Zone Assessment is designed to integrate the conservation of biodiversity learning outcomes into one major assignment. It can be used in one class or expanded to several classes, depending on the amount of fieldwork incorporated or the number of case studies examined. A general conservation dilemma (e.g., the clearing of riparian zones for beach property) or a local riparian issue (e.g., local stream/riverbank erosion or development) could be presented.

The learning activity is based on the work done by the Alberta Riparian Habitat Management Society (commonly known as Cows and Fish) to promote riparian awareness. Their focus is on agricultural issues related to riparian zones, which may appeal to students in agricultural communities. Many resources for this learning activity are available on the Cows and Fish website. Other riparian issues may have a recreational or industrial focus. Development along the banks of the Red River in Winnipeg is one such example.

Resource Links

The following resources are available from the Alberta Riparian Habitat Management Society, also known as Cows and Fish.

Alberta Riparian Habitat Management Society—Cows and Fish. Home Page. <www.cowsandfish.org>.

———. *Cows and Fish Fact Sheets*. <www.cowsandfish.org/publications/fact_sheets.html>.

Fact sheet on a variety of topics are available in the *Publications* section of the Cows and Fish website, including the following:

- *Biodiversity and Riparian Areas: Life in the Green Zone*
- *Crops, Creeks and Sloughs: Managing Riparian Areas in and around Cropland*
- *The Economic, Social and Environmental Value of Wetlands*
- *Facing the Issues*
- *Lakes and Wetlands*
- *Looking at My Lakeshore: Riparian Health Checklist*
- *Looking at My Streambank: Riparian Health Checklist*
- *Riparian Health Assessment and Inventory*
- *Water Quality and Riparian Areas*

These Cows and Fish fact sheets focus on the practical aspects of assessing the health of a riparian zone. The simplest forms are the two checklists. Students can be trained in using the checklists.

Fitch, Lorne, and Norine Ambrose. *Riparian Areas: A User's Guide to Health*. Lethbridge, AB: Cows and Fish Program, 2003. Available on the Alberta Riparian Habitat Management Society—Cows and Fish website at <www.cowsandfish.org/riparian/usersguide.html>.

This publication is promoted by Manitoba Habitat Heritage Program, Manitoba Agriculture and Food, Riparian Health Council, and local conservation districts to promote sustainable land management practices involving cattle grazing and riparian areas.

Along the Water's Edge. Prod. Fisheries and Oceans Canada, with input from Cows and Fish, 1995. Video.

This video interviews ranchers using riparian zones in their operations. Additional information about this video is available on the Land Stewardship Centre of Canada website at <www.landstewardship.org/resources/resource/387/>.

Part 1: Importance of Riparian Zones

Students are to

- identify what a riparian zone is
- describe what healthy riparian areas do
- give examples of how riparian zones conserve biodiversity

Teaching Tips

- Provide students with the following Cows and Fish fact sheet for general discussion and background information:
  - *Biodiversity and Riparian Areas: Life in the Green Zone*
- Show pictures/slides of various landscapes and ask students to identify riparian zones based on the three criteria identified in *Riparian Areas: A User's Guide to Health* (Fitch and Ambrose 4):
  - "Clue 1: Lots of water is present, seasonally or regularly and that water is either on the surface or it's close to the surface."
  - "Clue 2: Vegetation is present that responds to, requires and survives in abundant water."
  - "Clue 3: Soils have been modified by abundant water (as in high water tables), stream or lake processes (like sediment deposition) and lush, productive vegetation."
- Discuss key ideas such as the following:
  Healthy riparian zones
  - trap and store sediment
  - build and maintain banks and shorelines
  - store water and energy
  - recharge aquifers
  - filter and buffer water
  - reduce and dissipate energy
  - maintain biodiversity
  - create primary productivity

Part 2: Riparian Zone Assessment

Students are to

- examine a local riparian zone (stream bank or lakeshore)
- determine whether the riparian zone is healthy

Teaching Tips

- Provide students with one or both of the following Cows and Fish fact sheets:
  - *Looking at My Lakeshore: Riparian Health Checklist*
  - *Looking at My Streambank: Riparian Health Checklist*

  The checklists contain information on assessing the health of riparian zones. They focus on the vegetation, streambank and stream channel, water quality, and wildlife in the riparian area.

- Demonstrate how to use the checklists by showing pictures/slides of riparian zones and discuss with students what the scores from the checklists mean.
- This is an excellent opportunity to integrate a fieldwork component into the course. Students can use their checklists to assess an area, survey plant populations with transects or quadrats, and identify species with field guides and dichotomous keys.
- If you choose not to go on a field trip, present a new area to students with pictures/slides and plant samples. Students can complete the checklists and determine what the riparian health score means for ecosystem biodiversity.

Part 3: Issue Analysis

Students are to investigate an issue related to a riparian zone, focusing on

- identifying the issue and its parameters
- describing possible courses of action and resulting consequences
- making a recommendation that is the most ecologically sustainable

Teaching Tips

- "Today, riparian areas attract a variety of urban, recreational, industrial and agricultural activities" (Alberta Riparian Habitat Management Society, *Biodiversity and Riparian Areas* 4). Some of these uses contribute to the health of the riparian zone, while others do not. Work through a case study of one particular situation in a riparian zone.
- Key management ideas:
  - Prevent potential problems by maintaining healthy riparian zones.
  - Reduce pressures or stresses on the area.
  - Encourage and protect native vegetation.
  - Fix problem areas (e.g., improved paths, fencing).
  - Monitor progress in maintaining riparian health (long term).
  - Work as a community of stakeholders to improve the area.
- If you wish to examine an agricultural issue, consider the grazing of livestock in riparian zones. The Cows and Fish website has numerous consumer and producer stories that could be used. The video A*long the Water's Edge* (Fisheries and Oceans Canada) interviews ranchers using riparian zones in their operations.
- The issue of water quality, particularly in Lake Winnipeg, is an ongoing concern. Newspaper articles are readily available on the topic. Issues include the alteration of the lakeshore, erosion, and agricultural runoff.
- The impact of recreation on a riparian zone (e.g., motorboat wave action on shorelines, cottage and resort development) could be analyzed. The management plan for a lake in a provincial park could be examined, as the plans set out the type of recreation allowed on the lake (e.g., motorized boats, no cottage development). Create a scenario in which a developer makes a proposal to develop a resort hotel on a lake. What impact would such a development have? How could it be done to maintain a sufficient riparian zone?

Appendix 5.3B: Riparian Zone Assessment (BLM)

Introduction

> Riparian areas, especially those in prairie environments, support high levels of natural biodiversity. The combination of water, lush vegetation and connections to other landscapes provides opportunities for many species . . . . Riparian areas create important corridors that link a variety of ecosystems together. Species and genetic material travel easily through these small, but unique, pieces of the landscape. (Alberta Riparian Habitat Management Society, *Biodiversity and Riparian Areas 2*)

This three-part learning activity is intended to promote riparian awareness. The focus is on agricultural issues related to riparian zones.

Part 1: Importance of Riparian Zones

You will

- identify what a riparian zone is
- describe what healthy riparian areas do
- give examples of how riparian zones conserve biodiversity

Part 2: Riparian Zone Assessment

You will

- examine a local riparian zone (stream bank or lakeshore)
- determine whether the riparian zone is healthy

Part 3: Issue Analysis

You will investigate an issue related to a riparian zone, focusing on

- identifying the issue and its parameters
- describing possible courses of action and resulting consequences
- making a recommendation that is the most ecologically sustainable

Appendix 5.4A:
Fieldwork Skills Checklist—General Skills (BLM)

Name ____

General Skills	Expectations	Meeting Expectations	Not Yet Meeting Expectations
The student			
is prepared to conduct the fieldwork	reads the pre-lab outline before the task, creates tables, and asks questions that clarify the task, instead of asking "What do I do next?"		
sets up and uses equipment properly	chooses the correct equipment, sets up properly (e.g., transect line), and uses equipment properly (e.g., quadrats, field guide)		
follows safety procedures	demonstrates general safety procedures, as well as specifics outlined in the pre-lab		
records observations	records own observations as the work is occurring, uses quantitative and qualitative approaches as directed, and records in an organized fashion (e.g., uses a table or key)		
works independently (individual tasks) or works cooperatively (group tasks)	knows task and gets right to work or shares tasks and observations, is a good listener, and is receptive to other students' points of view		
manages time efficiently	divides and orders tasks to meet deadlines		
demonstrates consideration for the environment	minimizes disturbance to the site and species studied, leaves site clean, and takes away equipment		

Appendix 5.4B:
Fieldwork Skills Checklist—Thinking Skills (BLM)

Name ____

Thinking Skills	Questions	Understanding of Lab		
		Specific	General	Limited
Knowledge/ Comprehension	• What is the purpose of doing this work? • How does this relate to what you are studying in class? • What is the rationale for your hypothesis? • Why do you need special safety considerations for fieldwork?			
Application/ Analysis	• How did you decide on this procedure? • Are you having any difficulties with this procedure? • Are you getting the results that you expected? • How would you set up a graph, diagram, or flow chart to depict these results? • Do you see a pattern in your data? • Do any data points not follow the pattern?			
Synthesis/ Evaluation	• What can you conclude from your results? • Give a specific piece of evidence to support your conclusion. • What sources of error occurred in this trial? • What would you do differently in a second trial? What would you do the same? • How do your two trial results compare?			

Appendix 5.5A: Take a Stand (Teacher Background)*

Using a space large enough to accommodate the class, designate one end of the space as "Totally Agree" and the other end as "Totally Disagree." A line connecting the two opposite poles can be marked with masking tape to represent the continuum of positions that lie between.

Read an issue scenario out loud, providing students with a paper copy or using the overhead if needed. Then ask students to find a position on the line that reflects their opinion on the issue. Once students are in place, ask for explanations of why they chose their particular stand. Encourage students to respond to the opinions stated by others, but do not permit them to attack another's position.

Explain to students they are free to adjust their positions on the line as they hear ideas they have not previously considered, as a reflection of their changing views on the issue.

This learning activity can be used at the beginning of a topic of study to stimulate interest, discussion, and research, and does not depend on students having any special expertise on the issue. Repeated at the end of the topic, this learning activity can be used to assess what students have learned over a period of time, and how their views have changed as a result of their learning.

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* Source: Greene, Alanda. "Where Do You Stand?" *Green Teacher 54* (Winter 1997–98): 19–21. Adapted with permission. For information about this non-profit Canadian magazine, visit <www.greenteacher.com> or call 888-804-1486.

Appendix 5.5B: Take a Stand—Scenarios*

1. Fish Now or Later?

   Mike has made a living for himself and his family for the last 20 years as a commercial fisherman on Lake Winnipeg. He recently purchased a new, larger fishing boat. The payments on his boat are high, but Mike and his crew can work more safely and efficiently.

   Mike's neighbour Ramon is a freshwater biologist who works for the government. He has been studying fish populations in the lake over the past 10 years and is supporting a large reduction in the amount of commercial species (pickerel and whitefish) that can be caught in a year. Ramon says "My research shows that the numbers of fish in the lake is declining. We need to cut back on the quotas assigned to fishers."

   "I can't have my quota cut back," replies Mike. "I have to make my payments on my boat, and have a family to support. My crew needs their jobs as well. Why don't you do something about the pollution in the lake that is causing the fish stocks to decline?"

   Ramon replies to Mike's concerns by saying, "If we don't act now, there won't be any fish left in a few years. The fish are at great risk. Look what happened to the East Coast cod fishery."

   "There still are lots of fish in the lake," answers Mike, "and I expect to catch my fair share, which is why I bought my new boat. How else can I pay for it? How else can I earn a living?"

   Where do you stand on the question of cutting back on fishing quotas? (Mike's position)

2. Wolves and Cattle

   Wolves are natural inhabitants of Yellowstone National Park in Montana and Wyoming, but humans killed off all the wolves in the region in the early 1900s. After many years of work, environmental groups convinced the US government to release a pack of wolves in the park in order to re-establish a wolf population in the area.

   Sarah works for Wolves in the Wild. She says that wolves must return to these wild areas because they are an important part of the ecosystem, and will help restore the natural population balance of many wildlife species. "We destroyed these animals in what was their natural habitat. It's only right that we return the wolves to their natural habitat. It isn't the same country without the wolves."

   Pete is a rancher. He points out wolves don't know about park boundaries, and says there's no way to protect his cattle from them. "They're as happy to bring down a heifer as they are to kill a deer," claims Pete, "and I shouldn't have to have my cattle's lives threatened. This is now, not 75 years ago. The wolves are gone. Let them stay away. I have to make a living."

   Where do you stand on the question of introducing wolves back into the park? (Sarah's position)

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* Source: Greene, Alanda. "Where Do You Stand?" *Green Teacher 54* (Winter 1997–98): 19–21. Adapted with permission. For information about this non-profit Canadian magazine, visit <www.greenteacher.com> or call 888-804-1486.

Note: In 1995 and 1996 wolves were captured from Canada and released in Yellowstone National Park. An additional 10 were moved from northern Montana into the park in 1997. Tracking and scat analysis has shown that concerns over cattle predation by wolves have not materialized.

For more information on the Yellowstone Wolf Project, visit the following website:
U.S. National Park Service. "Wolves of Yellowstone." Y*ellowstone National Park*.
<www.nps.gov/yell/naturescience/wolves.htm>

Appendix 5.6A: Investigating Population Size (BLM)

Problem

What methods are used to estimate the size of plant and animal populations?

Introduction

It can be difficult to determine the size of plant and animal populations. This is why biologists use a variety of sampling strategies to estimate the size of populations in an area. Plant populations can be sampled with *transects* or *quadrats*, which are plots within which the number or type of species are counted in randomly selected areas. The size of a mobile animal population can be estimated by *mark and recapture*, in which the organism of study is tagged or banded.

These techniques are based on random sampling statistical procedures. Care must be taken to assure that randomness occurs when the sampling is performed, otherwise the erroneous population estimates will result.

Biologists can then determine whether a population is growing or declining by repeating sampling procedures over time.

Purpose

In this investigation, you will estimate population size using transect and quadrat sampling and the mark and recapture method.

Materials (per student group)

- biology textbook
- ruler
- microscope slide cover slip
- opaque jar or coffee can with a lid containing rice grains
- felt-tip marker
- calculator

Procedure

Part 1: Transect Sampling

1. Select one page at random from your biology textbook.
2. Hold the ruler flat over the page at a height of 10 cm. Close your eyes and drop the ruler.
3. Slide the ruler so that it extends the length or width of the page. One side of the length of the ruler is the transect line.
4. Count the number of letter *e*'s (small and capital) along the transect line. Record this in your Data Table.
5. Select another page at random in your textbook. Repeat steps 2 to 4 an additional four times, recording your data after each trial.

Part 2: Quadrat Sampling

1. Obtain a microscope slide cover slip. This is the quadrat.
2. Select one page at random from your biology textbook.
3. Hold the cover slip 10 cm away from the textbook. Gently toss the cover slip onto the page.
4. Count the number of letter *e*'s (small and capital) in the quadrat. Record this in your Data Table.
5. Select another page at random in your textbook. Repeat steps 2 to 4 an additional four times, recording your data after each trial.

Part 3: Mark and Recapture

1. Obtain a jar or can containing grains of rice. The rice represents an animal population. Your teacher will assign your group a specific number of rice grains to be picked out and marked. The number will be 50, 100, or 150, and will represent the number of animals captured for the first time and marked (M). Record this number in your Data Table.
2. Take turns removing your assigned number of rice grains from the can. Use a marker to colour the grains of rice you removed.
3. After allowing the ink to dry, place the coloured rice grains back into the container. Shake the container well.
4. Your teacher will assign you a specific number of rice grains to be picked out a second time. The number will be either 60 or 120, and will represent the number of animals captured a second time (C). Record this in your Data Table.
5. Remove the cover of the can and, without looking into the can, draw out the number of assigned rice grains from the can. Count how many grains of rice are the marked ones (recaptured). Record this as R Trial 1 in your Data Table.
6. Return all the rice grains to the container. Shake the can well and repeat step 5, removing the same number of rice grains. Record the number of marked rice grains as R Trial 2.
7. Repeat step 6. Record the number of marked rice grains as R Trial 3.
8. Determine the average of your three recapture trials and record this in your Data Table as the average R value.
9. With your group partners, count the total number of rice grains in the can. Record this in your Data Table as the actual number of rice grains.

Data Table

Part 1: Transect Sampling

Trial	Number of Letter e's
1	
2	
3	
4	
5	

Part 2: Quadrat Sampling

Trial	Number of Letter e's
1	
2	
3	
4	
5	

Part 3: Mark and Recapture

Step	Number
M (number of rice grains picked the first time and marked)	
C (total number of rice grains picked the second time)	
R Trial 1 (number of rice grains recaptured)	
R Trial 2 (number of rice grains recaptured)	
R Trial 3 (number of rice grains recaptured)	
Average R value	
Actual number of rice grains in the can	

Analysis

Part 1: Transect Sampling

1. Calculate the average number of letter *e*'s on a page of your textbook.
2. Calculate the number of *e*'s in your textbook. Multiply the average number of *e*'s per page by the number of pages in the book.

Part 2: Quadrat Sampling

1. Calculate the average number of letter *e*'s on a page of your textbook.
2. Calculate the number of *e*'s in your textbook. Multiply the average number of *e*'s per page by the number of pages in the book.
3. Share your results with the class by placing your calculation of the number of *e*'s in the textbook on the board, and record them in the table below.

Group	Number of Letter *e*'s in Textbook

Part 3: Mark and Recapture

1. Calculate the estimated size of your population using the following formula:

   $N = \frac{MC}{R}$ where

   N = total number of individuals in a population
   M = number of animals marked and released (50, 100, or 150)
   C = total number of animals caught in the second sample (60 or 120)
   R = average number of marked animals caught in the second sample (recaptured)
2. How does your population estimate compare to the actual number of rice grains?

3. Calculate the percent error in your estimation using the following formula:

$$\text{percent error} = \frac{\text{estimate} - \text{actual}}{\text{actual}} \times 100$$

4. Share your results with the class by placing your percent error values on the board, and record them in the table below.

	Recapture Sample Size	
Size of Marked Sample	60	120
50		
100		
150		

5. What is the effect of a large marked sample size on the percent error?
6. What is the effect of a large recapture sample size on the percent error?

Conclusions

1. Compare your quadrat estimate with your transect estimate of the number of *e*'s in the textbook. Why might your results differ?
2. Compare your quadrat estimate with that of your classmates. Why might the estimates vary?
3. If you were conducting a mark and recapture population estimate in the field, what sampling sizes would you choose to optimize your results? Explain.
4. Why is random sampling important in the techniques used to estimate the sizes of populations?
5. Manitoba Hydro is building a dam on a river that has a lake sturgeon population. This rare species has been declining in numbers across the province. You are the wildlife biologist in charge of determining how the sturgeon population would be affected when the river is dammed.
   a) How would you go about making an estimate of the existing sturgeon population?
   b) How would you determine whether or not the dam had an impact on the sturgeon population in the river?

Appendix 5.6B: Investigating Population Size (Answer Key)

Analysis

Part 1: Transect Sampling

1. Calculate the average number of letter *e*'s on a page of your textbook.

   Answers will vary.

2. Calculate the number of *e*'s in your textbook. Multiply the average number of *e*'s per page by the number of pages in the book.

   Answers will vary.

Part 2: Quadrat Sampling

1. Calculate the average number of letter *e*'s on a page of your textbook.

   Answers will vary.

2. Calculate the number of *e*'s in your textbook. Multiply the average number of *e*'s per page by the number of pages in the book.

   Answers will vary.

3. Share your results with the class by placing your calculation of the number of *e*'s in the textbook on the board, and record them in the table below.

   Answers will vary.

Part 3: Mark and Recapture

1. Calculate the estimated size of your population using the following formula:

   $N = \frac{MC}{R}$ where

   N = total number of individuals in a population
   M = number of animals marked and released (50, 100, or 150)
   C = total number of animals caught in the second sample (60 or 120)
   R = average number of marked animals caught in the second sample (recaptured)

   Answers will vary.

2. How does your population estimate compare to the actual number of rice grains?

   Answers will vary.

3. Calculate the percent error in your estimation using the following formula:

   $$\text{percent error} = \frac{\text{estimate} - \text{actual}}{\text{actual}} \times 100$$

   Answers will vary.

4. Share your results with the class by placing your percent error values on the board, and record them in the table below.

   Answers will vary.

5. What is the effect of a large marked sample size on the percent error?

   The larger the marked sample size is, the lower the percent error will be.

6. What is the effect of a large recapture sample size on the percent error?

   The larger the recapture sample size is, the lower the percent error will be.

Conclusions

1. Compare your quadrat estimate with your transect estimate of the number of *e*'s in the textbook. Why might your results differ?

   The results may differ due to the samples selected (whether they were truly selected randomly) and the small sample size (only five trials).

2. Compare your quadrat estimate with that of your classmates. Why might the estimates vary?

   The estimates could vary because each group used small samples and a small number of trials.

3. If you were conducting a mark and recapture population estimate in the field, what sampling sizes would you choose to optimize your results? Explain.

   I would use large sample sizes for both marking and recapture, as they tend to give results closer to the actual numbers.

4. Why is random sampling important in the techniques used to estimate the sizes of populations?

   If samples are not randomly selected, estimates could be significantly higher or lower than the actual population.

5. Manitoba Hydro is building a dam on a river that has a lake sturgeon population. This rare species has been declining in numbers across the province. You are the wildlife biologist in charge of determining how the sturgeon population would be affected when the river is dammed.

   a) How would you go about making an estimate of the existing sturgeon population?

   I could use a mark and recapture method before the dam is built. I would capture a number of sturgeon, tag them, and release them. Then, I could advertise to people who fish in the area, asking anyone catching sturgeon in the lake to let me know, and, if a tagged sturgeon was caught, to send me the tag number. People wouldn't need to take the tag off the fish. Because it is illegal to keep any sturgeon you catch in Manitoba, I know the sturgeon will be released.

   b) How would you determine whether or not the dam had an impact on the sturgeon population in the river?

   I would use a mark and recapture method again a few years after the dam was built. Because the tags would still be on the sturgeon, I could use the same method as I used previously. Then I would compare the population sizes I calculated before and after the dam was built. If the population size increased or decreased significantly, then I could say the hydro dam did have an effect on the size of the sturgeon population.

Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background)

> "Introducing students to the criteria by which their work will be evaluated enables students to better understand the characteristics of good performance."
>
> (White and Frederiksen 28)

By providing students with the opportunity to construct the criteria by which an assignment will be judged, students are better able to understand the goals of the assignment, are more likely to engage in the task, and are better able to produce quality work.

In their book *Setting and Using Criteria: For Use in Middle and Secondary School Classrooms*, Gregory, Cameron, and Davies outline a four-step process for developing assessment criteria with students:

1. Brainstorm a list of ideas.
2. Sort and categorize the ideas.
3. Make a T-chart.
4. Use, revise, and refine.

To be most effective in guiding students to complete the task successfully, the first three steps of the process should be done as students are introduced to the assignment, or are beginning work on the assignment.

Step 1: Brainstorm

After introducing the assignment, lead the class in brainstorming a list of ideas of what is important in the assignment. Questions such as "What is important to include in a research report?" or "What defines quality work in a lab report?" or "What counts in an oral presentation?" will help students generate ideas. Record students' ideas and contribute your own ideas to ensure the important assignment features are included.

What is important to include in a quality research report?

A research report should include

- different sources of information (e.g., websites, magazines, books)
- minimum of three sources of information (teacher input)
- organization into paragraphs
- introductory, body, and concluding paragraphs
- thesis statement
- bibliography
- standard style of citation and documentation (teacher input)
- details supporting thesis statement
- good spelling and grammar
- clear sentences
- conclusion
- word processing or neat writing
- title page
- expository writing

Step 2: Sort and Categorize

Have students examine the list generated in the first step to determine whether any of the ideas are related. Ask probing questions such as, "Can you find any ideas that seem to fit together?" or "Does this idea fit better with this group, or should it be in a new group?"

As the class comes to agreement on the groupings of ideas, develop headings that describe the groupings. Limiting the number of criteria to between three and five will help students focus on a manageable number of aspects of quality.

What is important to include in a quality research report?

A research report should include

1. different sources of information (e.g., websites, magazines, books)
2. minimum of three sources of information (teacher input)
3. organization into paragraphs
4. introductory, body, and concluding paragraphs
5. thesis statement
6. bibliography
7. standard style of citation and documentation (teacher input)
8. details supporting thesis statement
9. good spelling and grammar
10. clear sentences
11. conclusion
12. word processing or neat writing
13. title page
14. expository writing

Communicating information: 9, 10, 12, 13, 14
Organizing information: 3, 4, 6, 7
Using information: 1, 2, 5, 8, 11

Step 3: Make a T-Chart

Create a T-chart listing the criteria and specific details of the criteria. Clarify details or add more specific details if needed. The T-chart can be posted on the classroom wall or copied into notebooks for student reference.

Criteria for Research Report	Specific Details
Communicating Information	good spelling and grammar clear sentences word processing or neat writing title page expository writing
Organizing Information	organization into paragraphs introductory, body, and concluding paragraphs standard style of citation and documentation
Using Information	minimum of three different sources of information thesis statement details supporting thesis statement conclusion summarizing the report (more specific detail)

Step 4: Use, Revise, and Refine

As students work on the assignment, have them review the T-chart and examine their work in relation to the criteria and specific details. Are they meeting the criteria? Work should be revised to meet the criteria. If necessary, additional details can be added to further refine the criteria. A rubric can be created by defining levels of performance for each of the criteria.

Criteria for Research Report	Specific Details
Communicating Information	good spelling and grammar clear sentences word processing or neat writing title page expository writing
Organizing Information	organization into paragraphs introductory, body, and concluding paragraphs standard style of citation and documentation
Using Information	minimum of three different sources of information thesis statement details supporting thesis statement conclusion summarizing the report (more specific detail)

Appendix 5.8: Checklist for Creating Visuals (BLM)

(Collages, Graphic Organizers, Posters)

Name ______________________________

Criteria	Yes	Could Be Improved
Instructions for the assignment were followed carefully.		
Visuals are appropriate for the audience.		
All components of the visuals relate specifically to the topic.		
Visuals are clearly identified by a prominent title.		
Visuals are large enough to be easily viewed by all.		
Images are clear, effective, and complete.		
The most important points are near the top.		
Text (writing, labelling) is kept to a minimum.		
Font is uniform and appropriately sized.		
Visuals are appropriately placed and spaced.		
Colour scheme helps promote intended message.		
Overall appearance is effective and draws attention.		
Things that are done well:		
Things that could be improved:		

Appendix 5.9:
Oral Presentation—Observation Checklist (BLM)

Name ______________________________

Criteria	Check If Observed	Comments
Organization		
Introduction and statement of purpose were included.		
Ideas were organized in a meaningful way.		
Necessary background information was provided.		
A strong conclusion was included.		
Content		
Topic was clearly defined and explained.		
Main points were clearly presented.		
Details to support main points were included.		
Appropriate vocabulary was used.		
Speaker was well-informed on the topic.		
Speaker stayed focused on the topic.		
Delivery		
Volume was appropriate for audience.		
Enunciation was clear and precise.		
Speech was appropriately paced.		
Speaker maintained frequent eye contact.*		
Body language was not too relaxed or too stressed.		
Speaker was sensitive to audience reaction, and adapted if necessary.		
Presentation Support		
Speaker used appropriate visual aids and supports.		
Visual aids and supports were integrated in the presentation.		
Pronunciation, spelling, and grammar were accurate.		
Overall presentation was enthusiastic and effective.		

* Consider cultural appropriateness.

Additional Comments

GENERAL APPENDICES

Appendix 6: Scientific Communication

One of the primary skill thrusts of Grade 12 Biology is that of providing many opportunities for *scientific communication*. Some of these instances will mimic the behaviours, traditions, and organizational aspects of a *scientific community*. Others are intended to be more authentic and directly promote student-centred development of skills related to the unique demands of communicating scientific ideas and results effectively.

The following strategies can be used in the science classroom to communicate scientific information. For additional information about the strategies, see the following teacher resources:

- *Senior Years Science Teachers' Handbook* (Manitoba Education and Training), abbreviated as *SYSTH*
- *Senior 3 English Language Arts: A Foundation for Implementation* (Manitoba Education and Training), abbreviated as *Senior 3 ELA*

Audience (Adaptation for)

Students adapt information, such as a paragraph in a textbook, for a different audience.

Booklet, Brochure, Pamphlet

Students may present information they have obtained through research or investigation in the form of a booklet, brochure, or pamphlet. This medium is most effective if the information to be represented involves a series of individual steps or points, and includes diagrams or pictures. Students involved in graphic arts may consider this an effective means of communication.

Cartoons

An individual scientific concept, rule (such as a safety rule), or law may be effectively communicated by a cartoon, an illustration, or a series of pictures.

Charts

Information or results that show related tendencies or patterns may be presented best in an organized chart. A flow chart may allow the steps of a process to become more apparent.

Concept Overview Frame (See *SYSTH* 11.25, 11.37)

After studying a concept, students may fill out a Concept Overview Frame. This will allow them to summarize what they have learned.

Data Table

Data measured during the course of an investigation are often best organized in a data table. The data table should have a title, labelled rows and columns, and the correct units. It may include several trials and the average values, as well as the equations used (in variable form). The data table should be prepared before the experiment begins.

Debates (See *SYSTH* 4.19)

Debates are effective in presenting divergent opinions and attitudes related to STSE issues. The debate usually draws on students' own positions on science-related social issues. Pro and con formats can be used to illustrate the main points and to create a dialectic within the debate. While the scenario is often make-believe, the debate provides a forum for personal commentary. Because students often hold debated opinions with greater personal conviction, the debate must be structured in a manner in which sensitivity to various points of view is accepted, if not agreed upon.

Suggested Organization of Debates

1. Select two small balanced groups of students who support divergent and opposing views on a science-related social issue.
2. Provide or have students research background information.
3. Students on each side of the issue prepare and coordinate their evidence to avoid redundant arguments.
4. Select a moderator to monitor time and response to questions.
5. Remind students to listen to and respect divergent points of view. Discourage the notion that only one viewpoint is correct.

Demonstrations

Demonstration of a technique or a procedure is an effective way to communicate an understanding of the process.

Diagrams

Visual communication is often more effective than a written description. Labelled diagrams may be useful for showing equipment set-ups, cycles, and so on.

Dramatic Presentations

Many creative students enjoy dramatizing the information to be presented (such as the history of science) in the form of a skit, a role-play, a play, or a movie. Students must be prepared to research appropriate materials before constructing the dramatic presentation, as this process may be time-consuming. Care must be taken to ensure that students concentrate on the scientific concepts and knowledge, not solely on the dramatization.

Graphing

Representing data in graphical form helps make the relationship between variables more obvious.

- When planning the graph, students need to consider scale. They determine the maximum values for both axes and make the scale accordingly.
- Students label both the vertical and horizontal axes with the factors being graphed and indicate the units being used.
- If the points indicate a straight line, students may use a straight edge. If a line of best fit is required and calculated on the calculator, students need to represent their calculations accurately.
- In a sentence or two below the graph or within the analysis, students explain the implications or main point revealed by the representation.

Historical Perspectives

Students communicate information from the perspective of an individual (scientist, layperson) in another time period. They may choose to write an article critiquing an idea that was controversial in its time (such as smallpox vaccination or the Earth's orbit). Students research information and reflect on their response. Variations include responding from a different age or cultural perspective.

Inquiry or Research Paper Handbook (See *Senior 3 ELA* 4–270)

Working in groups, students produce a handbook outlining the various stages, processes, and strategies of the inquiry or research process. This handbook is then available as a reference during the course of study, and may be adapted or supplemented as required.

Journals

A scientific journal is an effective way for students to record thoughts and ideas during the progression of learning. Teachers may ask students to reflect on and respond to particular questions, such as noting their thoughts on a current issue in the newspaper. Alternatively, students may record their thoughts and feelings as they read a certain piece of scientific literature.

Learning Logs

Students keep an inquiry or research log throughout their inquiry or research project. In this log, students may collect various artifacts representing stages in the research process, as well as record anecdotes of the experience.

Microthemes

When provided with a case study, students interpret the events and express their ideas in a short written assignment. A microtheme may require specific thinking skills (e.g., creating an analogy, analyzing data, examining more than one point of view), and writing must be concise, detailed, and accurate. See Appendix 2.8A: Microthemes (Teacher Background) for more information.

Models

Students may create two- or thee-dimensional models of a particular concept, theory, or idea. This may involve the use of materials such as papier mâché or modelling clay.

Multimedia Presentations

Students may choose to communicate their understanding through the use of PowerPoint software, a video, or other types of electronic media.

Newspaper Articles

By writing as reporters from a particular period of a society's history, students may see different perspectives of a scientific issue or idea.

Oral Presentations

Gaining ease, composure, and a public presence while speaking to an audience are skills developed over many years of schooling and extracurricular activity. At certain points in a student's experience, some growth is encouraged in the arena of public oracy. When oral presentations are compulsory for students, teachers are encouraged to exercise caution and discretion. Focusing on these situations as celebrations of learning that students have mastered promotes confidence and success in addressing peers publicly.

Posters

The poster session at scientific meetings has long been a standard in scientific communication, and provides an alternative venue for the presentation of new results to the large-scale public lecture that is not able to engage at a personal level. In a poster presentation, there is ample opportunity to "get close" to the creators of the work, ask questions, point out interesting facets of their work, and offer suggestions for continued efforts.

Presentation Software

Students may use presentation software, such as PowerPoint, to present their information. Students must determine which sounds and images are suitable and enhance communication, as well as learn how to use the program's elements to unify their presentation.

RAFTS (Role-Audience-Format-Topic and Strong Verb) (See *SYSTH* 13.23 for Format)

The RAFTS writing assignment is a portfolio strategy designed to produce creative and imaginative writing pieces in science. Through these assignments, students can

- see alternative perspectives on a science topic or issue
- uncover divergent applications of science concepts
- make connections between their world of experience and their science learning (e.g., metaphorical stories)

Recommendation Report (See *Senior 3 ELA* 4–270)

Students write a short reflection on the implications of their inquiry findings. In their reflections, students may wish to

- identify subsequent inquiry topics that might grow out of the one they have researched
- suggest how the information gathered in the inquiry could be applied
- recommend action that should be taken to solve a problem
- explore how public awareness could be raised about an issue
- describe how they will think or act differently because of the inquiry

Role-Playing (See *SYSTH* 4.18)

Role-playing scenarios teach selected social processes that govern relations, such as negotiation, bargaining, compromise, and sensitivity. Ultimately, students would use these skills as they move from vision to action in dealing with STSE issues. Role-playing often provides an avenue for presenting biased opinions, which may or may not agree with the opinions of students. Most importantly, it introduces divergent points of view and allows students to analyze and respond, thereby giving them an opportunity to gain an appreciation for why individuals hold divergent points of view. Ideally, the role-playing scenario fosters critical-thinking skills while promoting tolerance of other world views. All simulations have rules that govern human interaction. Regardless of the roles assumed, certain behaviours should be promoted, while others should not be allowed.

Roundtable

A roundtable discussion should engage all students in open scientific discussion. The discussion may be initiated by concepts outlined in a scientific article. The opening question should engage all participants and should be based on the text of the article. Although it is not necessary, the teacher may ask *each* student to respond briefly to the first question to "break the ice." (Examples of opening questions are: "What is the most important idea in this text? Why?" and "Do you think this text is scientifically valid? Why?") The core question may be changed during the roundtable discussion to clarify a response or to refocus the group. This question should be focused more directly on the text. (For example: "Why did the scientists use [this animal, technique, equipment]?" or "Explain what the author meant by the word ______ in Paragraph 4.") This question should encourage students to examine how their thinking has changed during the course of the roundtable discussion. The teacher may want to ask questions (such as "How have your answers to the opening question changed?" or "How does the topic relate to your lives?" or "What could be done next?" or "What would you change?"). These questions should not solicit answers to which everyone would agree.

- **Role of Teacher:** The teacher's role is to facilitate, not validate. Try not to make any response, whether with a facial expression, nod, or frown, that would indicate a right or wrong answer. Ask questions that provoke and take thought to a new level. Remind students to back up thoughts with facts from the document. An idea might be to diagram the seating arrangement, "web" the responses, and add a word or phrase beside the name of the speaker. This strategy can help

— identify who speaks and how often

— provide cues to additional questions

— keep the teacher from physically affirming responses

If one student appears to monopolize the roundtable, each student may be issued five chips. Each time the student speaks, he or she gives up a chip. Therefore, the student has five opportunities to speak.

- **Role of Student:** Student participation (both speaking and listening) is mandatory. Students need to be courteous and respectful of classmates. They speak without raising their hands, talk to each other, and address the person they are speaking to by name. A roundtable is a way for students to communicate what they think about the document, not what they feel. They should always refer to the text.

Scientific Paper (See *SYSTH* 14.13 for Format)

At the Senior Years, exposure to the writing of a technical, scientific "paper" is of utmost importance, but it should be treated in an introductory manner. Many students face the reading (or writing) of the scientific paper rather suddenly at the post-secondary level of study, and are ill-prepared for it. In reality, particular scientific journals have their own writing style, format, and so on. No single format or referencing style should be advocated exclusively, but exposure to a few examples is helpful (for instance, using an American Psychological Association [APA] style of referencing versus numerical endnotes).

In the *Senior Years Science Teachers' Handbook*, teachers are offered some standard, normative samples of the Laboratory Report Format and the Scientific Paper Format (see *SYSTH*, Chapter 14: Technical Writing in Science, 14.11 to 14.15). Keep in mind that one of the chief purposes of the classical scientific paper is to announce the results of research related to *new contributions* in a field. Consequently, its role and purposes are distinct from those of a research or position paper.

Storyboard

Students could create storyboards to show the development of a scientific concept or theory. Discussion may then centre on the suggestion: "What might have happened if the order of occurrence had been changed?" (changing chronology).

Web Page Creation (See *Senior 3 ELA* 4–168)

Stages of creating a website may include

- surveying other websites on the same subject
- compiling a list of criteria for an effective website on the chosen subject
- writing a proposal for the website, describing its intended audience and purpose
- using a flow chart for constructing a personal website or contributing to the school's website

Word Cycle, Word Glossary (See *SYSTH* 10.21)

A Word Cycle is considered a strategy in building a scientific vocabulary (for instance, see *SYSTH*, Chapter 10: Building a Scientific Vocabulary). The value in using a Word Cycle comes from taking a broad concept such as an ecosystem, providing a list of terms that could be related to that concept, and then asking students to link these words coherently. Students then learn how terminologies are related, broaden meaning of terms, and promote collaboration. Teachers are encouraged to use Word Cycle learning activities with their students in a cooperative manner (e.g., pairings).

A Word Glossary, steadily accumulated over time, is a useful way for students to organize the large number of terms that science topics bring forth. Pay close attention to the repetitive use of prefixes (e.g., chrono-) and suffixes (e.g., -logical) in scientific parlance.

Written Laboratory Report (See *SYSTH* 11.38, 11.39, 14.12)

There are a variety of formats for lab reports within a common framework. A lab report may contain the following information:

- **Abstract/Introduction:** A condensed version of the entire paper, placed at the beginning of the report. The material in the abstract is written in the same order as it appears within the paper, and should include a sentence or two summarizing the highlights from each section. The abstract is written once the paper is complete.
- **Purpose/Objective/Problem:** A brief statement of the purpose or objective of the experiment.
- **Background Information:** Information drawn from research.
- **Pre-Lab Theory:** The posing of a theoretical solution to the problem before the experimental procedure. It may involve a conceptual explanation and mathematical calculations.
- **Hypothesis:** Contrary to the persistent myth, a hypothesis is not an "educated guess" about what will happen. A statement such as "cigarette smoking causes cancer" is a hypothesis because it is a statement of suggested behaviour in the material world that is *testable* by scientific means. A hypothesis intends to make a *contingent claim* based on prior accepted models about how the world works. The claim, then, is subject to testing over and over again. It is the task of the investigation procedure either to support or to nullify the hypothesis statement.
- **Variables:** For the purposes of this curriculum, anything that comes in different types or different amounts and could possibly enter into an investigation. The simplest sort of relationship to examine is that between two variables (e.g., a person's height and arm span). It is not always a simple task, however, to *control* all the variables that may confound a scientific investigation.
- **Materials:** A list of the materials to be used in the experiment and a labelled diagram of equipment set-up, if applicable.

- **Procedure:** Written step-by-step directions for performing the experiment and regulating the controls, and a summary of the steps taken, so that someone who has not performed this lab would be able to repeat it. If a mixture is heated, the temperature should be given. Any modifications to the procedure should be noted. When following a procedure from a secondary source, reference should be given for the source.
- **Results:** Include drawings, measurements, averages (if applicable), observations, data tables, calculations, and graphs.
- **Observations:** Qualitative interpretations of what is occurring during the course of an experiment. Examples include colour changes, odour, formation of a precipitate, release of gas, temperature differences, pressure changes, or changes in solubility.
- **Quantitative Data:** Measurements taken directly from laboratory instruments. Data must be collected with care during the experiment, properly identified, and the correct numerical values and units used. Suspected faulty data must be presented and explained in the conclusions if not used in the analysis.
- **Sample Problems:** Show the conversion of data into results. Calculations should be properly labelled, with the accuracy and precision of the instruments taken into consideration, and the correct number of significant figures used.
- **Analysis:** An important part of the report that demonstrates an understanding of the experiment. It contains an interpretation or explanation of results, indicating their significance, how accurate the original hypothesis was, sources of error and their effect on results. The analysis also indicates ways to improve the experiment, including modifying the procedure, the equipment, the variables, and so on. The analysis can relate results to the real world and may describe a follow-up or auxiliary experiment.
- **Conclusions:** A summary of results and whether the purpose of the experiment has been achieved. Readers often read the conclusion first.

Zines (See *Senior 3 ELA* 4-166)

Zines (or fanzines, or mini-magazines) usually treat a particular theme. Components may include

- cartoon
- collage
- editorial
- interview
- memoir
- poem
- review
- survey results

Appendix 7: Research

Learning through student-directed or student-initiated projects is known to be a highly effective pathway to promote individualized instruction or to make the best use of the diversity within the classroom. The inquiry approach advocated in Grade 12 Biology presupposes that students will have ample opportunity to develop and refine their research skills through gathering, filtering, processing, and evaluating scientific information.

The following learning strategies can be used in the science classroom to help students develop research skills and strategies. For additional information about the strategies, see the following teacher resources:

- *Senior Years Science Teachers' Handbook* (Manitoba Education and Training), abbreviated as *SYSTH*
- *Senior 3 English Language Arts: A Foundation for Implementation* (Manitoba Education and Training), abbreviated as *Senior 3 ELA*

Action Plan (See *Senior 3 ELA* 4–216 for Whole-Class Inquiry)

Students may submit action plans for group inquiries that include the following components.

Group Inquiry Action Plan					
Objectives	**Strategies**	**Responsibilities**	**Timelines**	**Results**	**Resources**

Concept Maps (See *SYSTH* 9.6, 11.7, 11.8, 11.11)

A Concept Map is intended to help students identify key vocabulary for a topic or identify the relationships between terms in a topic. The teacher may model this procedure by arranging pieces of paper with key terms to show the relationships or logical connections between them. Concept Maps may follow a category, a chain, or a hierarchy as an organizational strategy.

Email

The teacher can arrange links with schools, universities, or other research facilities in other parts of Canada or the world to have students carry out parallel research and to share and discuss data through email.

Interviews (See *Senior 3 ELA* 4–240, 4–226)

Students may analyze models of interviews and practise with peers before conducting interviews in the community. It may be useful to have a preliminary interview in which students introduce themselves, describe the topic and purpose, ask the interviewee what information or experience he or she is able to relate on the topic, explain how the interview will be conducted and how the information will be used, and discuss the time, length, and place of the interview.

Literature-Based Research Projects (See *SYSTH* 4.7)

A literature-based research approach can be applied to many STSE topics. A series of questions can direct students during their topic research. Students with competent literature research skills will be able to

- locate and analyze the validity of scientific information
- reduce unnecessary duplication of laboratory investigations
- recognize multiple perspectives from various interest groups
- determine how decisions are made at the local, provincial, and federal levels of government
- examine scientific, environmental, technological, societal, and economic sides of an issue

Teachers should model the five stages of effective research: planning, information retrieval or gathering, information processing, information sharing, and evaluation.

Plagiarism (Avoidance of)* (See *Senior 3 ELA* 4–260)

Teachers use direct instruction to teach students the conventions for summarizing, paraphrasing, and quoting from research materials. To avoid plagiarism, students need opportunities for supervised practice in using secondary sources appropriately in their research.

Three Ways to Use Secondary Sources (Student Handout)
• **Summaries:** Summarize general information as you proceed with your research. General information consists of facts and concepts that are generally known and that appear in several sources. If you cannot judge whether information is generally known or is the property of one writer, you need to read several more sources. When you write your own text, synthesize the facts and concepts from these summaries in your own words. This information does not need to be referenced. • **Paraphrases:** Paraphrase ideas and statements that belong to one writer, but that you do not wish to quote. To paraphrase, restate the ideas in a passage in your own words. You may need to use common words that appeared in the original, but do not repeat striking words or unique phrases that can be recognized as the style of the original writer. Reference the source of this material. It is considered good style to name the original writer in your paraphrase (e.g., Eldon Craig argues that the hog-nosed snake is a newcomer to Manitoba prairies.). • **Quotations:** Quote striking or powerful lines that would lose their impact if they were paraphrased. Take care to quote lines accurately, and ensure that you do not lose or change their meaning by taking them out of their original context. Make arguments in your own words, and support them with a quotation rather than using quotations to make key arguments. Name the speaker or writer you are quoting, enclose the quoted material in quotation marks, and reference the source of the quotation.

* Source: Manitoba Education and Training. *Senior 3 English Language Arts: A Foundation for Implementation.* Winnipeg, MB: Manitoba Education and Training, 1999. Section 4, p. 260.

A form such as the following can help students distinguish between material cited directly and their own paraphrases, summaries, and comments.

Form for Recording Information	
Author's name (last) ______________ (first) ______________ Title of source ______________ Place of publication ______________ Publisher ______________ Year of publication ______________	
Summaries Briefly note the main ideas of the whole text.	**Paraphrases** Write important and supporting information in your own words. Record the page number(s).
Comments Record your own responses to questions about what you read.	**Direct Quotations** Record only passages that you are very likely to quote in your final article. Record the page number(s).

Proposals (See *Senior 3 ELA* 4–221)

Students may submit proposals for major group projects. Depending on the project, the proposal may include the following categories:

- Purpose
- Audience
- Outline
- Resources
- Team Members and Their Responsibilities
- Steps in Research
- Risk Factors and Plans for Addressing Them
- Form for Reporting
- Timelines
- Progress Reports
- Criteria for Success

Reading Scientific Information (See *SYSTH*, Chapter 12)

Chapter 12 of *SYSTH* presents strategies to help students acquire the skills they need to comprehend science texts and scientific information accessed from multimedia sources. Students use interactive and collaborative strategies to understand and learn the content.

Good readers begin by skimming and analyzing a text and providing themselves with a structural and conceptual framework into which new information might fit. They then read for detail, with three levels of comprehension: literal understanding, interpretation, and application.

Students will be able to become better readers if teachers divide reading exercises into three sections:

- **Pre-reading:** Pre-reading strategies are intended to establish a purpose or focus, to activate prior knowledge, to emphasize new terms and vocabulary, or to provide familiarity with text features.
- **During-reading:** During-reading strategies are meant to promote collaboration, to help students recognize text structure, or to promote questioning and paraphrasing.
- **Post-reading:** Post-reading strategies are designed to teach students how to apply content by increasing comprehension and recall, connecting details to the big picture, making new connections, applying ideas, and transferring knowledge.

Various strategies are developed in *SYSTH*.

Surveys and Questionnaires (See *Senior 3 ELA* 4–226, Appendix C)

Students may submit a proposal for a survey or questionnaire in which they describe

- type of information they wish to gather
- type of survey they intend to implement
- target group and plan for random sampling
- how and when they will pilot the survey
- how and when they will administer the survey
- how they will analyze, interpret, and report data

Surveys are a useful tool for collecting information, particularly on timely, community-based inquiry topics. The following should be considered when designing and conducting a survey:

- purpose
- appropriateness
- practicality
- clarity
- reliability
- target group
- sample
- random selection

Types of surveys include fixed-response questions (multiple choice, agree-disagree, checklists), rating scales (numerical, categorical), open-ended, and phenomenological (extended interview). Students may choose to pilot their survey before administering it.

WebQuest

A WebQuest is an inquiry-oriented activity in which most or all of the information used by learners is drawn from the Web. WebQuests are designed to make efficient use of time, to focus on using information rather than looking for it, and to support learners' thinking at the levels of analysis, synthesis, and evaluation.

A basic WebQuest design includes an introduction, a task, a set of information sources needed to complete the task (not all sources need to be web-based), a description of the process in clear steps, guidance (such as guiding questions, timelines, Concept Maps), and a conclusion. WebQuest design information, templates, and samples may be obtained at WebQuest.org <http://webquest.org/>.

NOTES

Appendix 8: Assessment

For the purpose of this curriculum, assessment is the systematic process of gathering information about what a student knows, is able to do, and is currently *learning to do*. Science education today, therefore, demands a broad range and variety of assessment tools to gauge student learning. An inclusive classroom will encourage, whenever possible, assessment opportunities that provide *all students* with the chance to demonstrate what they know *most of the time*.

This appendix provides an overview of various assessment perspectives intended to promote fair assessment and evaluation and increase students' role and responsibility in their own ongoing assessment. Some actual assessment instruments that are proving to be effective in today's classrooms are also included.

Teachers are encouraged to review the *Senior Years Science Teachers' Handbook* (see *SYSTH*, Chapter 15: Assessing and Evaluating Science Learning). Further information is also provided in *Senior 3 English Language Arts: A Foundation for Implementation* (Manitoba Education and Training), abbreviated as *Senior 3 ELA* on the following pages.

Concept Relationship Frame (See *SYSTH* 11.20, 11.25, 11.35)

This differentiated instruction technique is designed to help students examine particular, detailed associations between two concepts (i.e., cause/effect, problem/solution, either/or, compare/contrast). The aim is to avoid superficial analysis by probing for deeper associations. Chapter 11: Developing Science Concepts Using Graphic Displays in *SYSTH* demonstrates how the Concept Relationship Frame can be used effectively.

Developing Assessment Rubrics in Science (See Appendix 9)

Appendix 9 outlines various ways in which students can be engaged with their teachers in the development of assessment rubrics. It addresses questions such as the following:

- What are assessment rubrics?
- Why do teachers use assessment rubrics?
- How can assessment rubrics enhance instruction?
- What are some sources of rubrics? Sources include classroom-developed, teacher-developed, and externally developed rubrics.

Journal Writing and Assessment (See *SYSTH* 13.21)

Journal writing is a *writing to learn* strategy that engenders mixed feelings among students. Part of the "uncertainty" comes from the inability to be passive about one's learning if one is asked to comment upon it, write carefully about it, or be reflective about it. Journals should have an *informal*, familiar tone but should not be quaint or dismissive. Journal entries can be simple and short, vary in frequency, and be structured to a particular format or free-form. It is valuable to consider how best to use journal writing in the science classroom, but experience shows that overuse defeats the purposes of the journal. For instance, if journal writing has little or no assessment/evaluation potential toward a student's grade, or does not provide a means of obtaining teacher feedback, it is difficult to sustain a successful experience.

Establishing a dialogue with students is an important element of formative assessment. Teachers may respond to students' journal entries, extending student thinking through comments and questions. In assessing journal entries, teachers may look for different interpretations and consideration of different perspectives, analyses, and growth.

Laboratory Report Assessment (See Appendix 10)

The Lab Report Assessment rubric is designed for both self-assessment and teacher assessment, and includes criteria categories such as the following:

- Formulates Testable Questions
- Formulates a Prediction and/or Hypothesis
- Creates a Plan
- Conducts a Fair Test and Records Observations
- Interprets and Evaluates Results
- Draws a Conclusion
- Makes Connections

Observation Checklist: Scientific Inquiry—Conducting a Fair Test (See Appendix 10)

This rubric is designed with five performance criteria, and can be used for an entire class list. The emphasis is on gathering information over time through observation. The criteria categories include the following:

- Demonstrating Safe Work Habits
- Ensuring Accuracy and Reliability
- Observing and Recording
- Following a Plan
- Showing Evidence of Perseverance and/or Confidence

Peer Assessment (See *Senior 3 ELA* 4–307)

Peer conferences could be organized to allow peers to act as problem solvers who offer concrete suggestions. The teacher may choose to provide students with questions and prompts. For instance, if students are editing a research paper, the peer assessment may include the following questions:

- Does the text contain enough information?
  - Pose questions that are not answered.
  - Mark passages that require more information.
- Is the text well-organized?
  - Use arrows to show suggested reordering of paragraphs.
  - Mark places where a transition is required.
- Is the text clear?
  - Mark passages that are clear.
  - Mark words or phrases that need to be explained or defined.
  - Mark passages that need charts, graphs, diagrams, or examples.
- Is the information communicated in an interesting way?
  - Mark the least and most interesting sections.
- Are the sources referenced?
  - Mark un-referenced information.
  - Suggest other sources that may be used.

Performance Assessment

Performance assessment may take the form of

- demonstrating a lab technique (e.g., lighting a Bunsen burner, using a micropipette, focusing a microscope)
- demonstrating a safety procedure
- interpreting Workplace Hazardous Materials Information System (WHMIS) labels
- identifying an unknown

Portfolios (See *Senior 3 ELA* 4–180)

Portfolio items that allow students to demonstrate attainment of specific learning outcomes include

- inquiry logs
- project proposals
- webs and maps
- samples of notes
- reports on primary research
- reflective pieces

Reading Scientific Information (Concept Map Evaluation) (See *SYSTH* 12.15 to 12.19)

Chapter 12: Reading Scientific Information in *SYSTH* suggests techniques for comprehending science texts. It includes examples of how students could take notes from text in the manner of a detailed Concept Map organizer (see 12.16) and how this strategy can connect to *reading for meaning*. Once teachers have effectively modelled the techniques and students have had ample time to practise with scientific reading skills and note-taking, some criteria can be established that can be used in evaluation (see 12.19).

References

Students hand in a preliminary list of references as part of their proposal for a research paper.

Rubric for Assessment of Class Presentation (See Appendix 10)

This rubric is designed with four performance levels, and includes assessment criteria categories such as the following:

- Content
- Interest and Enthusiasm
- Clarity and Organization of Materials
- Use of Visual Aids

Rubric for Assessment of Research Project (See Appendix 10)

This rubric is designed with four performance levels, and includes criteria categories such as the following:

- Source of Information
- Information Collected
- Organization of Material
- Presentation of Material

Rubric for Assessment of Scientific Inquiry (See Appendix 10)

This rubric is designed for guidance of student assessment in relation to the performance of *scientific inquiry tasks.* The rubric is not intended to be comprehensive, but seeks to provide some project-management parameters for teachers who are observing their students' initial attempts at sophisticated investigation work.

The rubric is designed around four levels of competency, as continua, and includes criteria in the following areas:

- Development of a Position Statement (Proto-Abstract)
- Objective/Purpose/Testable Question
- Procedure (design of the investigation)
- Data Collection
- Analysis and Interpretation of Results
- Application/Discussion of Scientific Results and Concepts
- Independence Factors (measuring degree of reliance upon outside assistance)

Self-Assessment

Self-assessment by students is integral to the overall assessment of learning. To assess their own work, however, students require some detailed advance knowledge (e.g., criteria) of what the expectations are. More advanced learners in this self-reflection process can then participate in setting criteria with their teacher(s). Teachers are encouraged to model self-assessment before expecting students to assess themselves.

Word Cycle (See *SYSTH* 10.6 to 10.8, 10.21)

A Word Cycle is considered a Level 1 strategy in building a scientific vocabulary (see *SYSTH*, Chapter 10: Building a Scientific Vocabulary). The value in using a Word Cycle comes from taking a broad concept such as an ecosystem, providing a list of terms that could be related to that concept, and then asking students to link these words coherently. Students then learn how terminologies are related, broaden the meaning of terms, and promote collaboration. Teachers are encouraged to use Word Cycle learning activities with their students in a cooperative manner (e.g., pairings).

NOTES

Appendix 9: Developing Assessment Rubrics in Science*

The Nature, Purposes, and Sources of Assessment Rubrics for Science

What Assessment Rubrics Are

Rubrics are assessment tools that identify criteria by which student processes, performances, or products will be assessed. They also describe the qualities of work at various levels of proficiency for each criterion.

The following types of assessment rubrics may be used in classroom assessment:

- **General rubrics** provide descriptions of proficiency levels that can be applied to a range of student processes, performances, or products. Using the same rubric for similar tasks helps teachers manage marking assignments based on student choice. It also helps students internalize the common qualities of effective processes, performances, and products.
- **Task-specific rubrics** describe the criteria used in assessing specific forms, such as using a balance, writing a laboratory report, or calibrating CBL probes. Complex student projects may require a different rubric for each phase (for example, a group inquiry project may require a rubric for collaborative work, information-gathering processes, oral presentations, and written reports).
- **Holistic rubrics** are used to assign a single mark to a process, performance, or product on the basis of its adequacy in meeting identified criteria.
- **Analytic rubrics** are used to assign individual scores to different aspects of a process, performance, or product, based on their specific strengths and weaknesses according to identified criteria. See the Rubric for Assessment of Decision-Making Process Activity in Appendix 10.
- **Checklists** are lists of criteria that do not distinguish levels of performance. They are used to assess the presence or absence of certain behaviours, and are most suitable for assessing processes (for example, "Did the student perform all the necessary steps?"). Because they require "Yes/No" judgments from the assessors, checklists are easy for students to use in peer assessment.
- **Rating scales** ask assessors to rate various elements of a process, performance, or product on a numerical scale. They do not provide complete descriptions of performance at various levels.

Why Teachers Use Assessment Rubrics

The best assessment tasks ask students to perform the sorts of scientific literacy tasks they will be called upon to perform in real-world situations. They allow students to demonstrate not only the declarative knowledge they have gained, but also the interplay of attitudes, skills, and strategies that constitute their learning.

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* Source: Manitoba Education and Training. *Senior 3 English Language Arts: A Foundation for Implementation.* Winnipeg, MB: Manitoba Education and Training, 1999. Adapted from Appendices, pp. 3 to 10.

Authentic assessment tasks invite a range of responses and allow students to express their individuality. For all these reasons, assessing scientific literacy is a complex matter.

Assessment rubrics

- help teachers clarify the qualities they are looking for in student work
- ensure that all students are assessed by the same criteria
- help teachers communicate the goals of each assignment in specific terms
- allow teachers within schools, school divisions, and the province to collaborate in assessment
- play an important part in instruction

How Assessment Rubrics Enhance Instruction

The best assessment tools do not simply sort and score student work; instead, they describe it in specific terms. This assessment information

- helps teachers adjust instruction to meet student learning requirements
- tells students what teachers expect and will look for in their work, and helps them to focus their efforts
- allows students to assess their own work using the criteria teachers will use to set goals and to monitor their progress
- aids in the development of metacognition by giving students a vocabulary for talking about particular aspects of their work

Sources of Assessment Rubrics

Teachers develop assessment rubrics in collaboration with students, on their own, and/or with other teachers, or obtain them through published sources.

- **Classroom development:** Developing assessment rubrics in collaboration with students can be a time-consuming process, but one that has many benefits in instruction and learning. (Both the benefits and the process are explored on the following pages.) Although it may not be possible to involve students in the process in every instance, their experience in developing rubrics will help students to use ready-made rubrics with more understanding.
- **Teacher-developed:** Teachers develop general performance and product rubrics individually in collaboration within a school or school division. Rubrics must be adapted regularly to reflect student performance levels accurately. It is important that teacher-developed rubrics use language that students understand, and that teachers provide an example of work at each level of proficiency. These examples (called anchors or exemplars) illustrate for students the descriptive phrases used in the rubrics.
- **Published sources:** High-quality assessment rubrics are available in various educational resources. The disadvantage of ready-made rubrics is that they may not be congruent with the learning outcomes targeted in a particular assignment, and may not accurately describe Grade 12 performance levels and criteria.

Developing Rubrics in Collaboration with Students

Student Benefits

Developing rubrics in collaboration with students requires them to look at work samples and to identify the attributes that make some samples successful and others unsuccessful. Teachers assist students by providing them with the vocabulary to articulate the various elements they see, and by ensuring that the criteria are comprehensive and consistent with learning outcomes. This collaborative process in developing rubrics

- requires students to make judgments about the work they see, and to identify the qualities of effective writing, speaking, and representing of science concepts
- results in an assessment tool that students understand and feel they own—they see that assessment criteria are not arbitrary or imposed, but rather express their own observations about what constitutes quality work

The Development Process

For their first experience in designing a rubric, ask students to articulate the criteria they use in making judgments about something in everyday life—the quality of a restaurant, for example. The model rubric that they develop for assessing restaurants may help students grasp how the parts of a rubric work.

Students may also find it helpful to develop rubrics after they have done some preliminary work on the assessment task, and so are familiar with the demands of the particular assignment.

The process of developing assessment rubrics in collaboration with students involves numerous steps.

1. ***Look at student work samples.***

   Develop assessment rubrics by analyzing genuine samples of student work that illustrate the learning outcomes that the assessment task in question addresses. Samples are usually drawn from student work from previous years, used with permission and with names removed. Beginning teachers who do not have files of samples may need to borrow from colleagues.

   Select samples that are clear and characteristic of student work at various levels. Streamline the process by distributing examples at only three levels of proficiency: excellent, adequate, and inadequate. Provide two or three examples of each level. Allow students time to read the examples and to talk about them in groups.

2. ***Describe the work samples.***

   Suggest that students focus on the examples of excellent work first. Pose the question: "What makes this piece successful?" Then ask students to brainstorm attributes of, or criteria for, success. Some of the attributes students list will describe behaviours that are useful in meeting the goals of the work (for example, the topic is stated at the beginning, there are few spelling errors, a graph is used to represent statistical findings).

What rubrics must attempt to articulate, beyond identifying these behaviours, is the essence of a good product or performance. As Wiggins points out, eye contact may be important in the delivery of an oral report, but it is possible to give a dreary talk while maintaining eye contact (V1-5: 6). Together with students, identify the salient qualities of works related to science that are engaging and effective. These may be qualities that are harder to define and illustrate (for example, the speaker has moved beyond a superficial understanding of the subject, the producer of a video is aware of the audience, the writer's voice is discernible in a science journalism piece).

3. ***Develop criteria categories.***

   From the brainstormed list of attributes, select the criteria categories that will make up the assessment rubric. Most rubrics are limited to three to five criteria categories. A greater number makes the rubrics difficult for assessors to use, especially in assessing live performances. Listing too many criteria can also overwhelm or confuse students who use the rubrics for self-assessment and setting goals.

   Develop criteria categories by combining related attributes and selecting three to five that are considered most important. Label the criteria categories in general terms (organization, style, content) and expand them by listing the specific elements to be examined in assessing quality in these criteria (for example, in the "organization" category, the elements may be statement of purpose, topic sentences, transition words and phrases, paragraph breaks, order of ideas).

   Ensure that no essential attribute that defines good performance is left out. This means including elements considered hard to assess (such as style or creativity). Ignoring elements such as these signals that they are not important. Addressing them helps students grasp the things they can do to improve their own work in these areas. If graphical analysis is identified as one criteria category, for example, the rubric may list elements that convey the details of such an analysis (for example, placement of dependent and independent variables, placement of data points, line of "best fit"). It may also provide definitions.

   As students collaborate to develop criteria categories, monitor whether the criteria chosen are related to the intended learning outcomes.

4. ***Decide how many performance levels the rubric will contain.***

   The first rubric students develop will have three performance levels, based on identifying student work samples as excellent, adequate, or inadequate. In later rubrics, students may move to finer distinctions between levels. The number of levels needed to make meaningful judgments regarding the full range of proficiency is best decided by the teacher. If the scale is large (seven levels, for example), finer distinctions can be made, but it may be difficult to differentiate clearly one level from the next. In science, assessment rubrics designed to be used by students as well as teachers generally use three, four, or five performance levels.*

Using the same number of performance levels for various tasks throughout the curriculum has the advantage of giving students and the teacher a common vocabulary in talking about ways to improve performance (for example, "This piece does not have the concrete detail of level 4 writing."). Once the number of criteria categories and performance levels has been determined, a rubric template such as the following can be used in developing rubrics.

		Criteria Categories			
Performance Levels	1				
	2				
	3				
	4				
	5				

5. ***Describe the performance levels.***

   In developing the assessment criteria (step 3), students analyze successful pieces of work. They now fill in descriptions of excellent, adequate, and inadequate performance in all criteria categories.

   There are two ways of describing performance levels:

   - **Evaluative rubrics** use comparative adjectives (for example, "weak organization").
   - **Descriptive rubrics** specify the qualities of work at each performance level with respect to the criteria (for example, "unconnected ideas appear in the same paragraph"). The attributes listed may be negative (for example, "subscripts and coefficients are incorrectly applied"), for sometimes the most telling characteristic of certain levels is their failure to do what they should be doing.

   Descriptive rubrics have many advantages over evaluative rubrics. They are more helpful to students because they spell out the behaviours and qualities students encounter in assessing their own and others' work. They also help students identify the things they can address in their own work in order to improve.

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* Many designers of rubrics advocate a five-level scale. Levels 1, 3, and 5 are developed from an initial sorting of student work into excellent, adequate, and inadequate samples. Levels 2 and 4 describe work that is between these anchor points. Other educators argue that an even-point scale (four or six levels) forces more care in judging than an odd number does; it prevents assessors from overusing a middle category for work that is difficult to assess.

When beginning to write descriptive rubrics, students may suggest generally descriptive adjectives (such as "interesting," "boring"), which may not convey information about what an interesting piece looks like, and how they can improve their work in this area. The description needs to state the attributes that make a work interesting, and should be written in an acceptable style for scientific communication. Classes may need to begin by using comparative language or general descriptions. As the students and teacher collect examples, they can fine-tune the rubric with specific descriptions.

By the end of this step, students will have a description of performance at three levels. If the class has decided to create a rubric with four, five, or six performance levels, it may be most efficient for the teacher to draft gradations of quality for the middle levels, and present them to the class for revision. These middle levels are the most difficult to write, and call on more experience and expertise in developing a smooth continuum of proficiency.

6. ***Use the assessment rubric for student self-assessment, for teacher assessment, and for instruction.***

   Before using the rubric on an actual assignment, students and the teacher may want to test it against unsorted samples of work from previous years. Applying the rubric to student work helps the class determine whether the rubric accurately describes the qualities of the work they see, and helps students make meaningful distinctions between work at different levels of proficiency. As students become more adept at using the rubric, and when they have internalized the performance levels, the teacher can present them with more diverse samples and assessment challenges.

   Rubrics make it possible for students to assess their own work on the basis of the criteria that the teacher will use. Any differences in scores between a student's and a teacher's assessment can be the subject of profitable and focused discussion in student conferences.

   If numerical scores are required, point values assigned to each level can be totalled. If the teacher and students decide that certain criteria categories should be more heavily weighted than others, the points assigned to these categories can be multiplied by a factor.

   A rubric developed collaboratively can also become a valuable instructional tool, encouraging students to look closely at the specific things they can do to improve a piece of work. If students decide that a writing sample in science is at level 3, for example, they can be asked to work together in groups to improve the work so that it fits the description for level 4.

7. ***Continue to revise the assessment rubric.***

   Any assessment rubric can be considered a work in progress, especially if it is stored on the computer. Both the teacher and students should carefully review the rubric each time they use it, asking, "Do these criteria capture the most important qualities of excellence in this work?" "What other words and phrases can we use to describe work at this level?" In keeping with this, the rubrics appearing in Appendix 10 of this document are intended as templates, open to situational revisions.

Appendix 10: Assessment Rubrics

Rubric for Assessment of Research Project

Student Name(s) ____________________ Topic/Title ____________________

Criteria	Performance Levels			
	Level 1	**Level 2**	**Level 3**	**Level 4**
Source of Information	❒ Only one source of information was used.	❒ Two sources of information were used.	❒ A variety of sources was used.	❒ A wide variety of sources was used in a unique manner.
Information Collected	❒ The information collected was not relevant.	❒ The information collected was relevant to the topic but was not blended into a cohesive piece of research.	❒ The information collected was relevant to the topic and was somewhat organized into a cohesive piece of research.	❒ The information collected was relevant to the topic and was carefully organized into a cohesive piece of research.
Organization of Material	❒ The information collected was not organized.	❒ The information was somewhat organized.	❒ The information was organized and contained recognizable sections.	❒ The information was organized and contained recognizable sections that included an introduction, a main body with supporting evidence, and a conclusion that summarized the report.
Presentation of Material	❒ The report was handwritten, contrary to established guidelines.	❒ The report was neatly handwritten. ❒ The report contained a bibliography that was not correctly formatted.	❒ The report was typed. ❒ The report contained graphics. ❒ The report contained a bibliography that was not correctly formatted.	❒ The report was typed and appropriately formatted. ❒ The report contained a title page. ❒ The report contained relevant graphics. ❒ The report contained a complete, correctly formatted bibliography.

Note: *This rubric would vary, depending on the assignment and the presentation format.*

Rubric for Assessment of Decision-Making Process Activity

Student Name(s) ______________________ Topic/Title ______________________

Criteria	Performance Levels			
	Level 1	**Level 2**	**Level 3**	**Level 4**
Identifies STSE Issue	❐ Cannot identify an STSE issue without assistance.	❐ Shows a basic understanding that an issue could have STSE implications, but does not necessarily differentiate among the areas.	❐ Shows a good understanding of a connection between an issue and its STSE applications. ❐ Shows some awareness of the need for an individual response.	❐ Demonstrates excellent depth and sensitivity in connecting an issue with its STSE implications. ❐ Demonstrates a level of social responsibility.
Evaluates Current Research on Issue	❐ Is able to access a small amount of current research but does not evaluate it.	❐ Demonstrates some ability to recognize the positions taken in the research data but makes no clear evaluative statements.	❐ Secures an array of research, narrow in its scope, but clearly identifies the positions taken. ❐ Can offer personal opinions on issue but not necessarily an evaluation.	❐ Acquires research that is current, relevant, and from a variety of perspectives. ❐ Demonstrates insight into the stated positions and can frame an evaluation.
Formulates Possible Options	❐ Is unable to identify the possible options clearly. ❐ Can formulate options that are not clearly connected to the problem to be solved.	❐ Offers at least one feasible option that is connected to the problem. ❐ Offers other options that may be somewhat related to the problem.	❐ Develops at least two feasible options that are internally consistent and directly address the problem. ❐ Recognizes that some options will fail.	❐ Displays a sophisticated understanding of feasible options that is beyond expectations. ❐ Presents choice of options that demonstrate a reasonable chance of succeeding.
Identifies Projected Impacts	❐ Is unable to foresee the possible consequences of the options selected. ❐ Appears to have a naive awareness of consequences.	❐ Identifies potential impacts of decisions taken in a vague or insubstantial way. ❐ Views most of the feasible options as having projected impacts.	❐ Identifies potential impacts of decisions taken in an organized way. ❐ Views all the feasible options as having projected impacts: some beneficial, some not.	❐ Offers a cost/benefits/risks analysis of each feasible solution. ❐ Constructs an organized report that clearly outlines the impacts of each option.

(continued)

Rubric for Assessment of Decision-Making Process Activity *(continued)*

Student Name(s) ____________________ Topic/Title ____________________

Criteria	Performance Levels			
	Level 1	**Level 2**	**Level 3**	**Level 4**
Selects an Option and Makes a Decision	❒ Is unable to come to a decision that clearly connects with the problem to be solved. ❒ Requires direction from the outside to make a choice.	❒ Identifies a feasible option, but cannot clearly decide on a plan. ❒ Requires outside influences to stand by a decision to proceed.	❒ Clearly selects an option and decides on a course of action, but others can identify that a better course of action remains untried. ❒ Recognizes potential safety concerns.	❒ Thoroughly analyzes all options collaboratively. ❒ Makes firm decision, justified by the research base, and recognizes most of the safety concerns.
Implements the Decision	❒ Is unable to implement the decision fully, but has an opportunity to modify it. ❒ Lacks the clarity to proceed.	❒ Implements the decision with a recognition that not all details are laid out in advance. ❒ Lacks clarity in having a plan for implementation.	❒ Implements the decision with some clarity of purpose. ❒ Demonstrates confidence that the implementation plan can follow a scientific inquiry approach.	❒ Implements the decision with clarity of purpose, backed by the research base. ❒ Clearly demonstrates that the implementation plan can be carried to completion as inquiry.
Identifies and Evaluates Actual Impacts of Decision	❒ Cannot clearly recognize more than one possible actual impact of the decision. ❒ Cannot effectively evaluate the effects of the decision taken.	❒ Can clearly recognize more than one possible actual impact of the decision taken. ❒ Cannot effectively evaluate the effects of the decision taken in most instances.	❒ Is able to recognize and comment upon the actual observed impacts of the decision. ❒ Demonstrates some ability to evaluate the impacts of the decision.	❒ Is able to recognize and comment deeply upon the actual observed impacts of the decision, noting unforeseen or unique outcomes. ❒ Is able to evaluate the impacts of the decision with ease.
Reflects on the Decision Making and Implementation of a Plan	❒ Begins to demonstrate an awareness of the need to review the implementation plan. ❒ Is reluctant to consider a re-evaluation of the plan.	❒ Reflects upon and intends to communicate the results of the implementation plan. ❒ Has some difficulty in knowing how to proceed with a re-evaluation of the problem-solving plan.	❒ Reflects upon and communicates the results of the implementation plan. ❒ Recognizes how to proceed with a re-evaluation of the problem-solving plan.	❒ Reaches higher order of synthesis in the reflection process. ❒ Has a sophisticated environmental awareness that informs this post-implementation period.

Note: *The above criteria are suggestions only, and will need to be adapted in collaboration with students according to the purpose of the assignment.*

Observation Checklist: Scientific Inquiry—Conducting a Fair Test

Names	Demonstrating Safe Work Habits (workspace, handling equipment, goggles, disposal)	Ensuring Accuracy and Reliability (repeating measurements/ experiments)	Observing and Recording (carried out during experiment)	Following a Plan	Showing Evidence of Perseverance and/or Confidence	Comments

Note: *A group of students can be selected as a focus for observation on a given day, and/or one or more of the observational areas can be selected as a focus. The emphasis should be on gathering cumulative information over a period of time.*

Lab Report Assessment

Project Title ____ Date ________________________

Team Members ____

Area of Interest	Possible Points	Self	Teacher
Formulates Testable Questions Question is testable and focused, and the cause-and-effect relationship is identified.			
Formulates a Prediction/Hypothesis Independent and dependent variables are identified and the prediction/hypothesis clearly identifies a cause-and-effect relationship between these two variables.			
Creates a Plan All steps are included and clearly described in a logical sequence. All required materials/equipment are identified. Safety considerations are addressed. Major intervening variables are controlled.			
Conducts a Fair Test and Records Observations Evidence of repeated trials is presented and all data are included. Detailed data are recorded, and appropriate units are used. Data are recorded in a clear/well-structured/appropriate format for later reference.			
Interprets and Evaluates Results Patterns/trends/discrepancies are identified. Strengths and weaknesses of approach and potential sources of error are identified. Changes to the original plan are identified and justified.			
Draws a Conclusion Conclusion explains cause-and-effect relationship between dependent and independent variables. Alternative explanations are identified. Hypothesis is supported or rejected.			
Makes Connections Potential applications are identified and/or links to area of study are made.			
Total Points			

Rubric for Assessment of Student Presentation

Student Name(s) ____________________ Topic/Title ____________________

Criteria	Performance Levels			
	Level 1	**Level 2**	**Level 3**	**Level 4**
Organization	❒ Presentation shows poor organization and lack of preparation.	❒ Presentation shows signs of organization, but some parts do not seem to fit the topic.	❒ Presentation is organized, logical, and interesting.	❒ Presentation is well organized, logical, interesting, and lively.
Preparation	❒ Some student preparation is shown.	❒ A fair amount of student preparation is shown.	❒ An adequate amount of student preparation is shown.	❒ A great deal of student preparation is shown.
Content	❒ Small amount of material presented is related to the topic.	❒ Some material presented is not related to the topic.	❒ Almost all material presented is related to the topic.	❒ All material presented is related to the topic.
Language	❒ Language used is hard to follow and understand.	❒ Some language used is hard to follow and understand.	❒ Most language used is easy to follow and understand.	❒ Language used is well chosen and is easy to follow and understand.
Format	❒ Poor use of aids and support materials (diagrams, overheads, maps, pictures); few support the topic.	❒ Adequate use of aids and support materials; most support the topic.	❒ Good use of aids and support materials; almost all support the topic.	❒ Excellent use of aids and support materials; all aids support the topic.
Delivery	❒ Many words are unclear or spoken too quickly or too slowly; voice is monotonous; no pausing for emphasis; voice is too low to be heard easily.	❒ Some words are unclear or spoken too quickly at times; voice is somewhat varied; some pausing for emphasis; voice is sometimes too low to be heard easily.	❒ Most words are clear and generally spoken at the correct speed; voice is often varied and interesting; frequent pausing for emphasis; voice is loud enough to be heard easily.	❒ Words are clear and generally spoken at the correct speed; voice is frequently varied and interesting; effective pausing for emphasis; voice is loud enough to be heard easily.
Audience	❒ Audience is not involved or interested.	❒ Audience is somewhat involved, and sometimes interested.	❒ Audience is involved and interested.	❒ Audience is very involved and interested.

Note: *The above criteria are suggestions only, and will need to be adapted in collaboration with students according to the purpose of the assignment.*

Rubric for Assessment of Class Presentation

Student Name(s) ____________________ Topic/Title ____________________

Criteria	Performance Levels			
	Level 1	**Level 2**	**Level 3**	**Level 4**
Content	❒ No understanding of the topic was evident.	❒ Basic understanding of the topic was evident. ❒ No attempt was made to relate material presented to students' own experiences.	❒ Good understanding of the topic was evident. ❒ Knowledge was thorough and detailed. ❒ Attempt was made to relate material presented to students' own experiences.	❒ Excellent depth of understanding was evident. ❒ Material presented went beyond what was required. Excellent research. ❒ Material presented related to students' own experiences.
Interest and Enthusiasm	❒ Presenter(s) displayed little interest in and enthusiasm for the topic of the presentation. ❒ The class conveyed limited attentiveness during the presentation.	❒ Presenter(s) showed some interest in and enthusiasm for the topic. ❒ The class showed some attentiveness during the presentation.	❒ Presenter(s) clearly showed interest in and enthusiasm for the topic. ❒ The class was noticeably attentive during the presentation.	❒ Presenter(s) showed exceptional interest in and enthusiasm for the topic. ❒ The class was keenly attentive during the presentation.
Clarity and Organization of Material	❒ The information presented was confusing.	❒ The information presented was somewhat vague. ❒ The presentation reflected some organization.	❒ The information was clearly presented. ❒ The presentation was well-organized.	❒ All information was relevant and clearly presented. ❒ The presentation was exceptionally well-organized. ❒ Main points were emphasized and reinforced with appropriate examples.
Use of Visual Aids	❒ Visual aids were not used.	❒ A few visual aids were used. ❒ Visual aids were not well done. ❒ Visual aids used were somewhat relevant to the presentation.	❒ Visual aids were used. ❒ Visual aids were quite well done. ❒ Visual aids were relevant to the presentation.	❒ Strong visual aids were used with care. ❒ Visual aids were clear and exceptionally well done, showing effective use of colour. ❒ Visual aids were designed to emphasize and strengthen the presentation and were successful.

Note: *This rubric would vary according to the assignment and the presentation format.*

Rubric for Assessment of Research Skills

Student Name(s) ______________________ Topic/Title ______________________

Research Skills	Performance Levels			
	Level 1	Level 2	Level 3	Level 4
Ability to formulate questions to identify problems for research purposes	☐ Shows limited ability	☐ Shows some ability	☐ Shows general ability	☐ Shows consistent and thorough ability
Ability to locate relevant primary and secondary sources of information	☐ Unable to locate	☐ Somewhat able to locate	☐ Generally able to locate	☐ Always or almost always able to locate
Ability to locate and record relevant information from a variety of sources	☐ Unable to locate and record	☐ Somewhat able to locate and record	☐ Generally able to locate and record	☐ Always or almost always able to locate and record
Ability to organize information related to identified problem(s)	☐ Shows limited ability	☐ Shows some ability	☐ Shows general ability	☐ Shows consistent and thorough ability
Ability to analyze and synthesize information related to identified problems	☐ Shows limited ability	☐ Shows some ability	☐ Shows general ability	☐ Shows consistent and thorough ability
Ability to communicate results of inquiries using a variety of appropriate presentation forms (oral, media, written, graphic, pictorial, other)	☐ Unable to communicate	☐ Somewhat able to communicate	☐ Generally able to communicate	☐ Always or almost always able to communicate

Note: *This rubric would vary according to the assignment and the presentation format.*

Rubric for Assessment of Scientific Inquiry

Student Name(s) ____________________ Topic/Title ____________________

Criteria	Performance Levels			
	Beginning 1	**Developing 2**	**Accomplished 3**	**Exemplary 4**
Position Statement/ Proto-Abstract (Not intended to be an abstract in the style and purpose of scientific journals)	The student ❒ does not discuss the relevance of the inquiry	The student ❒ offers some discussion but no clear explanation of the importance or goals of the inquiry	The student ❒ discusses the importance of the inquiry but not its relationship to the curriculum or to the real world	The student ❒ clearly summarizes the inquiry, highlights relevant information, and makes critical connections
Objective/Purpose/ Testable Question (Formulation of scientific questions and hypotheses)	❒ omits an objective/ purpose, or states an objective not relevant to the problem under investigation	❒ states an objective that is not a hypothesis or a testable question, but identifies variables to be investigated	❒ states a testable question related to the problem, and identifies variables to be investigated	❒ clearly states a testable hypothesis that addresses the problem, and clearly delineates the variables to be tested
Procedure (Design of the investigation)	❒ does not outline reproducible steps in the procedure ❒ shows some use of methodology, but no account of experimental or systematic error	❒ outlines clear, ordered steps in the procedure ❒ identifies need for treatment of variables, but does not state how this will be achieved	❒ outlines clear, ordered steps in the procedure ❒ identifies need for treatment of *specific* variables, and states how this will be achieved	❒ outlines clear, ordered steps in the procedure ❒ identifies need for treatment of *specific* variables, and states how this will be achieved ❒ provides a concise summary of the procedure
Data Collection	❒ collects some data that can be traced to the investigation itself, but data are inaccurate and incomplete	❒ provides reasonably complete data, organized in tabular form (+/– titles) ❒ gives no indication of use of basic accuracy and precision techniques (e.g., significant figures)	❒ provides complete data, organized in tabular form (+/– titles) ❒ demonstrates some use of basic accuracy and precision techniques (e.g., significant figures)	❒ provides complete data with error analysis, organized in tabular form (+/– titles) ❒ demonstrates use of basic accuracy and precision techniques (e.g., significant figures)

(continued)

Rubric for Assessment of Scientific Inquiry *(continued)*

Student Name(s) ____________________ Topic/Title ____________________

Criteria	Performance Levels			
	Beginning 1	**Developing 2**	**Accomplished 3**	**Exemplary 4**
Analysis and Interpretation of Results	❒ provides improper, incomplete graphical representation of data ❒ attempts no "fit" for plotted data ❒ requires abundance of supervision	❒ provides proper graphical representation of data ❒ attempts to fit a *linear* regression line to data ❒ ensures axes are labelled correctly and positioned consistently with identified variables	❒ provides proper graphical representation of data ❒ shows some evidence of mastery in fitting a *linear* regression line to data, and states *slope* and *y*-intercept ❒ ensures axes are labelled correctly and positioned consistently with identified variables	❒ provides proper graphical representation of data in a variety of forms ❒ shows evidence of mastery in fitting a *non-linear* regression model to data, and states *y*-intercept ❒ ensures axes are labelled correctly and positioned consistently with identified variables ❒ demonstrates understanding of how variables relate to a model equation
Application/ Discussion of Scientific Results and Concepts	❒ attempts to explain inquiry results in terms of random error alone ("where I went wrong") ❒ makes inaccurate, improper, or no conclusions based on data	❒ attempts to connect inquiry results with model systems encountered in class experience ❒ identifies where systematic error may have caused problems	❒ draws accurate and detailed comparison between the system under investigation and what could occur in an ideal system ❒ makes use of introductory statistical analyses ❒ identifies "outliers" in data set(s)	❒ draws accurate and detailed comparison between the system under investigation and what could occur in an ideal system ❒ uses a range of statistical analyses ❒ identifies "outliers" in data set(s)
Independence Factors (Reliance on assistance)	❒ requires extensive assistance from text sources and classmates to do inquiry tasks ❒ requires constant teacher supervision	❒ requires little assistance to complete inquiry tasks ❒ is able to internalize teacher intervention, and work independently afterward	❒ requires no assistance to complete inquiry tasks ❒ demonstrates cooperation with partners ❒ resists efforts of others to assist	❒ requires no assistance to complete inquiry tasks ❒ demonstrates cooperation with partners ❒ seeks opportunities to discuss procedures and results with others

Appendix 11: General and Specific Learning Outcomes

General Learning Outcomes

General learning outcomes (GLOs) provide connections to the Five Foundations for Science Literacy that guide all Manitoba science curricula in all science discipline areas.

Nature of Science and Technology

As a result of their Senior Years science education, students will:

A1 Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

A2 Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop.

A3 Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.

A4 Identify and appreciate contributions made by women and men from many societies and cultural backgrounds that have increased our understanding of the world and brought about technological innovations.

A5 Recognize that science and technology interact with and advance one another.

Science, Technology, Society, and the Environment (STSE)

As a result of their Senior Years science education, students will:

B1 Describe scientific and technological developments—past and present—and appreciate their impact on individuals, societies, and the environment, both locally and globally.

B2 Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and the societal context of the time.

B3 Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.

B4 Demonstrate knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.

B5 Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

Scientific and Technological Skills and Attitudes

As a result of their Senior Years science education, students will:

C1 Recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations.

C2 Demonstrate appropriate scientific inquiry skills when seeking answers to questions.

C3 Demonstrate appropriate problem-solving skills when seeking solutions to technological challenges.

C4 Demonstrate appropriate critical thinking and decision-making skills when choosing a course of action based on scientific and technological information.

C5 Demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind.

C6 Employ effective communication skills and use information technology to gather and share scientific and technological ideas and data.

C7 Work cooperatively and value the ideas and contributions of others while carrying out scientific and technological activities.

C8 Evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life.

Essential Science Knowledge

As a result of their Senior Years science education, students will:

D1 Understand essential life structures and processes pertaining to a wide variety of organisms, including humans.

D2 Understand various biotic and abiotic components of ecosystems, as well as their interaction and interdependence within ecosystems and within the biosphere as a whole.

D3 Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

D4 Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts.

D5 Understand the composition of the Earth's atmosphere, hydrosphere, and lithosphere, as well as the processes involved within and among them.

D6 Understand the composition of the universe, the interactions within it, and the implications of humankind's continued attempts to understand and explore it.

Unifying Concepts

As a result of their Senior Years science education, students will:

E1 Describe and appreciate the similarity and diversity of forms, functions, and patterns within the natural and constructed world.

E2 Describe and appreciate how the natural and constructed world is made up of systems and how interactions take place within and among these systems.

E3 Recognize that characteristics of materials and systems can remain constant or change over time, and describe the conditions and processes involved.

E4 Recognize that energy, whether transmitted or transformed, is the driving force of both movement and change, and is inherent within materials and in the interactions among them.

Cluster 0: Skills and Attitudes

Cluster 0 in Grade 12 Biology comprises various categories of specific learning outcomes that describe the skills and attitudes involved in scientific inquiry and the decision-making process for Science, Technology, Society, and the Environment (STSE) issues. From Grades 5 to 10, students develop scientific inquiry through the development of a hypothesis/prediction, the identification and treatment of variables, and the formation of conclusions. Students begin to make decisions based on scientific facts and refine their decision-making skills as they progress through the grades, gradually becoming more independent. Students also develop key attitudes, an initial awareness of the nature of science, and other skills related to research, communication, the use of information technology, and cooperative learning.

In Grades 11 and 12 Biology, students continue to use scientific inquiry as an important process in their science learning, but also recognize that STSE issues require a more sophisticated treatment through the decision-making process.

Teachers should select appropriate contexts to introduce and reinforce scientific inquiry, the decision-making process, and positive attitudes within the Grade 12 Biology units throughout the school year. To assist in planning and to facilitate curricular integration, many specific learning outcomes within the Skills and Attitudes cluster can link to specific learning outcomes in other subject areas.

Demonstrating Understanding

B12-0-U1 Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames…

B12-0-U2 Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concepts to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations…

Personal Perspectives/Reflection

B12-0-P1 Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-P2 Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-P3 Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

B12-0-P4 Recognize that humans have had and continue to have an impact on the environment. (GLO: B1, B2)

B12-0-P5 Appreciate that developments in and use of technology can create ethical dilemmas that challenge personal and societal decision making. (GLOs: B1, B2)

Scientific Inquiry/Problem Solving

B12-0-S1 Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S2 Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3 Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4 Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)
Include: discrepancies in data and sources of error

B12-0-S5 Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

Decision Making

B12-0-D1 Identify and explore a current health issue. (GLOs: C4, C8)

Examples: clarify the issue, identify different viewpoints and/or stakeholders, research existing data/information . . .

B12-0-D2 Evaluate implications of possible alternatives or positions related to an issue. (GLOs: B1, C4, C5, C6, C7)

Examples: positive and negative consequences of a decision, strengths and weaknesses of a position, ethical dilemmas . . .

B12-0-D3 Recognize that decisions reflect values, and consider own and others' values when making a decision. (GLOs: C4, C5)

B12-0-D4 Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-D5 Propose a course of action related to an issue. (GLOs: C4, C5, C8)

B12-0-D6 Evaluate the process used by self or others to arrive at a decision. (GLOs: C4, C5)

Information Management and Communication

B12-0-I1 Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2 Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3 Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4 Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Group Work

B12-0-G1 Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G2 Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-G3 Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Nature of Science

B12-0-N1 Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2 Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

B12-0-N3 Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

Specific Learning Outcomes

The specific learning outcomes (SLOs) identified here constitute the intended learning to be achieved by the student by the end of Grade 12 Biology. These statements clearly define what students are expected to achieve and/or be able to perform at the end of course. These SLOs, combined with the Skills and Attitudes SLOs, constitute the source upon which assessment and instructional design are based.

Part 1: Genetics

Unit 1: Understanding Biological Inheritance

B12-1-01 Outline Gregor Mendel's principles of inheritance, stating their importance to the understanding of heredity. (GLOs: A1, A2, B1, D1)

Include: principles of segregation, dominance, and independent assortment

B12-1-02 Explain what is meant by the terms *heterozygous* and *homozygous*. (GLO: D1)

B12-1-03 Distinguish between *genotype* and *phenotype*, and use these terms appropriately when discussing the outcomes of genetic crosses. (GLO: D1)

B12-1-04 Use Punnett squares to solve a variety of autosomal inheritance problems, and justify the results using appropriate terminology. (GLOs: D1, E1)

Include: monohybrid cross, dihybrid cross, testcross, P generation, F_1 generation, F_2 generation, phenotypic ratio, genotypic ratio, dominant alleles, recessive alleles, purebred, hybrid, and carrier

B12-1-05 Describe examples of and solve problems involving the inheritance of phenotypic traits that do not follow a dominant-recessive pattern. (GLO: D1)

Examples: co-dominance, incomplete dominance, multiple alleles, lethal genes . . .

B12-1-06 Explain the basis for sex determination in humans. (GLO: D1)

Include: XX and XY chromosomes

B12-1-07 Describe examples of and solve problems involving sex-linked genes. (GLO: D1)

Examples: red-green colour-blindness, hemophilia, Duchenne muscular dystrophy . . .

B12-1-08 Use pedigree charts to illustrate the inheritance of genetically determined traits in a family tree and to determine the probability of certain offspring having particular traits. (GLOs: C8, D1)

Include: symbols and notations used

B12-1-09 Discuss ethical issues that may arise as a result of genetic testing for inherited conditions or disorders. (GLOs: A3, B1, B2, C4)

B12-1-10 Discuss the role of meiosis and sexual reproduction in producing genetic variability in offspring. (GLOs: D1, E3)

Include: crossing over and randomness

B12-1-11 Explain how chromosome mutations may arise during meiosis. (GLOs: D1, E3)

Include: nondisjunction

B12-1-12 Identify monosomy and trisomy chromosome mutations from karyotypes. (GLO: D1)

Examples: Down syndrome, Turner syndrome, Klinefelter syndrome . . .

Unit 2: Mechanisms of Inheritance

B12-2-01 Outline significant scientific contributions/discoveries that led to the current understanding of the structure and function of the DNA molecule. (GLOs: A2, A4, A5, B1, B2)

Include: timeline, individual contributions, multidisciplinary collaboration, and competitive environment

B12-2-02 Describe the structure of a DNA nucleotide. (GLOs: D1, D3)

Include: deoxyribose sugar, phosphate group, and nitrogenous bases

B12-2-03 Describe the structure of a DNA molecule. (GLOs: D1, D3)

Include: double helix, nucleotides, base pairing, and gene

B12-2-04 Describe the process of DNA replication. (GLOs: D1, D3)

Include: template, semi-conservative replication, and role of enzymes

B12-2-05 Compare DNA and RNA in terms of their structure, use, and location in the cell. (GLOs: D1, D3)

B12-2-06 Outline the steps involved in protein synthesis. (GLOs: D1, D3)

Include: mRNA, codon, amino acid, transcription, tRNA, anticodon, ribosome, and translation

B12-2-07 Relate the consequences of gene mutation to the final protein product. (GLOs: D1, D3)

Examples: point mutation in sickle-cell anemia, frameshift mutation in β-thalassemia . . .

B12-2-08 Discuss implications of gene mutation for genetic variation. (GLOs: D1, E1, E3)

Include: source of new alleles

B12-2-09 Investigate an issue related to the application of gene technology in bioresources. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, economic implications, a variety of perspectives, and personal/societal/global implications

B12-2-10 Investigate an issue related to the application of gene technology in humans. (GLOs: A3, A5, B1, B2, C4, C5)

Include: understanding the technology/processes involved, ethical and legal implications, a variety of perspectives, and personal/societal/global implications

Part 2: Biodiversity

Unit 3: Evolutionary Theory and Biodiversity

B12-3-01 Define the term *evolution*, explaining how evolution has led to biodiversity by altering populations and not individuals. (GLOs: D1, E3)

Include: gene pool and genome

B12-3-02 Describe and explain the process of discovery that led Charles Darwin to formulate his theory of evolution by natural selection. (GLOs: A2, A4, B1, B2)

Include: the voyage of the *Beagle*, Darwin's observations of South American fossils, the impact of the Galapagos Islands on his thinking, and the work of other scientists

B12-3-03 Outline the main points of Darwin's theory of evolution by natural selection. (GLO: D1)

Include: overproduction, competition, variation, adaptation, natural selection, and speciation

B12-3-04 Demonstrate, through examples, what the term *fittest* means in the phrase "survival of the fittest." (GLO: D1)

Examples: stick insects blending with their environment, sunflowers bending toward sunlight, antibiotic-resistant bacteria . . .

B12-3-05 Explain how natural selection leads to changes in populations. (GLOs: D1, E3)

Examples: industrial melanism, antibiotic-resistant bacteria, pesticide-resistant insects . . .

B12-3-06 Describe how disruptive, stabilizing, and directional natural selection act on variation. (GLOs: D1, E3)

B12-3-07 Distinguish between *natural selection* and *artificial selection*. (GLOs: D1, E1, E3)

B12-3-08 Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. (GLOs: D1, E3)

Include: large population, random mating, no gene flow, no mutation, and no natural selection

B12-3-09 Discuss how genetic variation in a gene pool can be altered. (GLOs: D1, E1, E3)

Examples: natural selection, gene flow, genetic drift, non-random mating, mutation . . .

B12-3-10 Describe how populations can become reproductively isolated. (GLOs: D1, E2)

Examples: geographic isolation, niche differentiation, altered behaviour, altered physiology . . .

B12-3-11 With the use of examples, differentiate between *convergent evolution* and *divergent evolution* (adaptive radiation). (GLOs: D1, E1)

B12-3-12 Distinguish between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. (GLOs: D1, E3)

Unit 4: Organizing Biodiversity

B12-4-01 Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02 Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

B12-4-03 Describe the dynamic nature of classification. (GLOs: A1, A2)

Include: different systems and current debates

B12-4-04 Describe types of evidence used to classify organisms and determine evolutionary relationships. (GLOs: A2, A5)

Examples: fossil record, DNA analysis, biochemistry, embryology, morphology . . .

B12-4-05 Compare the characteristics of the domains of life. (GLOs: D1, E1)

Include: Archaea (Archaebacteria), Bacteria (Eubacteria), and Eukarya

B12-4-06 Compare the characteristics of the kingdoms in the Eukarya domain. (GLOs: D1, E1)

Include: cell structure, major mode of nutrition, cell number, and motility

B12-4-07 Investigate an evolutionary trend in a group of organisms. (GLOs: C2, C5, C6, E1)

Examples: hominid evolution, vascularization in plants, animal adaptations for life on land . . .

Unit 5: Conservation of Biodiversity

B12-5-01 Discuss a variety of reasons for maintaining biodiversity. (GLOs: B2, B5, D2)

Include: maintaining a diverse gene pool, economic value, and sustainability of an ecosystem

B12-5-02 Describe strategies used to conserve biodiversity. (GLOs: B2, B5, D2)

Examples: habitat preservation, wildlife corridors, species preservation programs, public education . . .

B12-5-03 Select and use appropriate tools or procedures to determine and monitor biodiversity in an area. (GLOs: C1, D2, C7)

Examples: field guides, dichotomous keys, quadrats, transects, mark and recapture . . .

B12-5-04 Investigate an issue related to the conservation of biodiversity. (GLOs: C4, C6, C8, D2, E2)

Examples: heritage seeds, water quality in Lake Winnipeg, land-use designations, hydroelectric development . . .

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Notes

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