Biology 3201

Curriculum Guide 2021

Newfoundland Labrador
Education

Department of Education Vision Statement

Building an educational community in Newfoundland and Labrador that fosters safe, inclusive, and healthy learning environments for all educators and students in the early learning, K-12 and post-secondary education systems.

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Section One: Newfoundland and Labrador Curriculum

Introduction

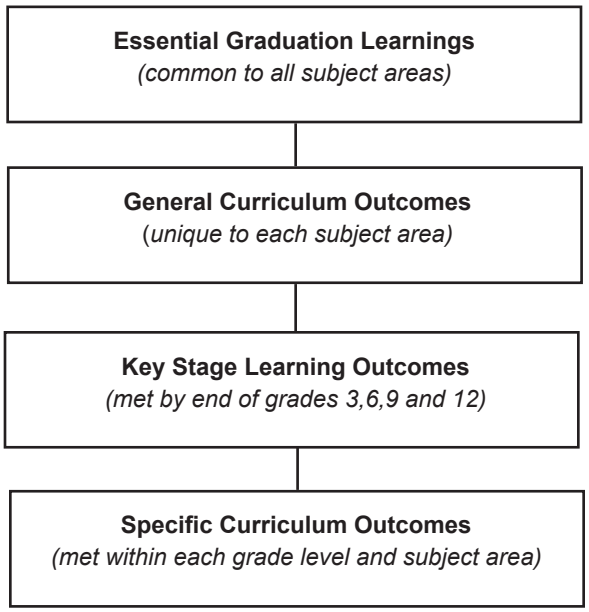
There are multiple factors that impact education: technological developments, increased emphasis on accountability, and globalization. These factors point to the need to consider carefully the education students receive.

The Newfoundland and Labrador Department of Education believes that curriculum design with the following characteristics will help teachers address the needs of students served by the provincially prescribed curriculum:

- Curriculum guides must clearly articulate what students are expected to know and be able to do by the time they graduate from high school.
- There must be purposeful assessment of students' performance in relation to the curriculum outcomes.

Outcomes Based Education

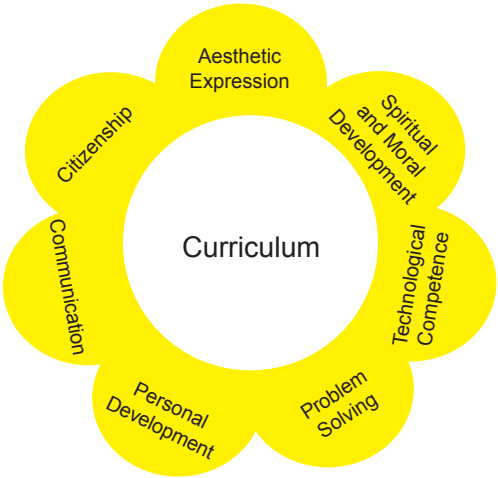
The K-12 curriculum in Newfoundland and Labrador is organized by outcomes and is based on *The Atlantic Canada Framework for Essential Graduation Learning in Schools* (1997). This framework consists of Essential Graduation Learnings (EGLs), General Curriculum Outcomes (GCOs), Key Stage Curriculum Outcomes (KSCOs) and Specific Curriculum Outcomes (SCOs).



Essential Graduation Learnings

EGLs provide vision for the development of a coherent and relevant curriculum. They are statements that offer students clear goals and a powerful rationale for education. The EGLs are delineated by general, key stage, and specific curriculum outcomes.

EGLs describe the knowledge, skills, and attitudes expected of all students who graduate from high school. Achievement of the EGLs will prepare students to continue to learn throughout their lives. EGLs describe expectations, not in terms of individual subject areas, but in terms of knowledge, skills, and attitudes developed throughout the K-12 curriculum. They confirm that students need to make connections and develop abilities across subject areas if they are to be ready to meet the shifting and ongoing demands of life, work, and study.



Aesthetic Expression – Graduates will be able to respond with critical awareness to various forms of the arts and be able to express themselves through the arts.

Citizenship – Graduates will be able to assess social, cultural, economic, and environmental interdependence in a local and global context.

Communication – Graduates will be able to use the listening, viewing, speaking, reading and writing modes of language(s), and mathematical and scientific concepts and symbols, to think, learn and communicate effectively.

Problem Solving – Graduates will be able to use the strategies and processes needed to solve a wide variety of problems, including those requiring language, and mathematical and scientific concepts.

Personal Development – Graduates will be able to continue to learn and to pursue an active, healthy lifestyle.

Spiritual and Moral Development – Graduates will demonstrate understanding and appreciation for the place of belief systems in shaping the development of moral values and ethical conduct.

Technological Competence – Graduates will be able to use a variety of technologies, demonstrate an understanding of technological applications, and apply appropriate technologies for solving problems.

Curriculum Outcomes

Curriculum outcomes are statements that articulate what students are expected to know and be able to do in each program area in terms of knowledge, skills, and attitudes.

Curriculum outcomes may be subdivided into General Curriculum Outcomes, Key Stage Curriculum Outcomes, and Specific Curriculum Outcomes.

General Curriculum Outcomes (GCOs)

Each program has a set of GCOs which describe what knowledge, skills, and attitudes students are expected to demonstrate as a result of their cumulative learning experiences within a subject area. GCOs serve as conceptual organizers or frameworks which guide study within a program area. Often, GCOs are further delineated into KSCOs.

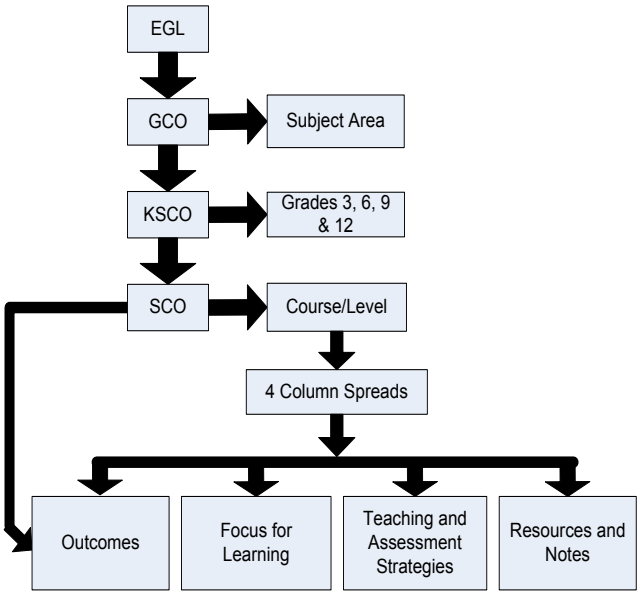
Key Stage Curriculum Outcomes (KSCOs)

Key Stage Curriculum Outcomes (KSCOs) summarize what is expected of students at each of the four key stages of grades three, six, nine, and twelve.

Specific Curriculum Outcomes (SCOs)

SCOs set out what students are expected to know and be able to do as a result of their learning experiences in a course, at a specific grade level. In some program areas, SCOs are further articulated into delineations. *It is expected that all SCOs will be addressed during the course of study covered by the curriculum guide.*

EGLs to Curriculum Guides



Context for Teaching and Learning

Teachers are responsible to help students achieve outcomes. This responsibility is a constant in a changing world. As programs change over time so does educational context. Several factors make up the educational context in Newfoundland and Labrador today: inclusive education, support for gradual release of responsibility teaching model, focus on literacy and learning skills in all programs, and support for education for sustainable development.

Inclusive Education

Valuing Equity and Diversity

Effective inclusive schools have the following characteristics: supportive environment, positive relationships, feelings of competence, and opportunities to participate. (The Centre for Inclusive Education, 2009)

All students need to see their lives and experiences reflected in their school community. It is important that the curriculum reflect the experiences and values of all genders and that learning resources include and reflect the interests, achievements, and perspectives of all students. An inclusive classroom values the varied experiences and abilities as well as social and ethno-cultural backgrounds of all students while creating opportunities for community building. Inclusive policies and practices promote mutual respect, positive interdependencies, and diverse perspectives. Learning resources should include a range of materials that allow students to consider many viewpoints and to celebrate the diverse aspects of the school community.

Differentiated Instruction

Differentiated instruction is a teaching philosophy based on the premise that teachers should adapt instruction to student differences. Rather than marching students through the curriculum lockstep, teachers should modify their instruction to meet students' varying readiness levels, learning preferences, and interests. Therefore, the teacher proactively plans a variety of ways to 'get it' and express learning. (Carol Ann Tomlinson, 2008)

Curriculum is designed and implemented to provide learning opportunities for all students according to abilities, needs, and interests. Teachers must be aware of and responsive to the diverse range of learners in their classes. Differentiated instruction is a useful tool in addressing this diversity.

Differentiated instruction responds to different readiness levels, abilities, and learning profiles of students. It involves actively planning so that the process by which content is delivered, the way the resource is used, and the products students create are in response to the teacher's knowledge of whom he or she is interacting with. Learning environments should be flexible to accommodate various learning preferences of the students. Teachers continually make decisions about selecting teaching strategies and structuring learning activities that provide all students with a safe and supportive place to learn and succeed.

Planning for Differentiation

Create a dynamic classroom:

- Manage routines and class organization.
- Present authentic and relevant communication situations.
- Provide realistic and motivating classroom experiences.

Respond to student differences:

- Allow for multiple ways to demonstrate learning.
- Empower through a gradual release of responsibility.
- Provide opportunities to take ownership of learning goals.

Vary teaching strategies:

- Enable students to collaboratively construct meaning in a positive learning community.
- Provide students with opportunities to make essential links to texts.

Differentiating the Content

Differentiating content requires teachers to pre-assess students to identify those who require prerequisite instruction, as well as those who have already mastered the concept and may therefore apply strategies learned to new situations. Another way to differentiate content is to permit students to adjust the pace at which they progress through the material. Some students may require additional time while others will move through at an increased pace and thus create opportunities for enrichment or more indepth consideration of a topic of particular interest.

Teachers should consider the following examples of differentiating content:

- Meet with small groups to reteach an idea or skill or to extend the thinking or skills.
- Present ideas through auditory, visual, and tactile means.
- Use reading materials such as novels, websites, and other reference materials at varying reading levels.

Differentiating the Process

Differentiating the process involves varying learning activities or strategies to provide appropriate methods for students to explore and make sense of concepts. A teacher might assign all students the same product (e.g., presenting to peers) but the process students use to create the presentation may differ. Some students could work in groups while others meet with the teacher individually. The same assessment criteria can be used for all students.

Teachers should consider flexible grouping of students such as whole class, small group, or individual instruction. Students can be grouped according to their learning styles, readiness levels, interest areas, and/or the requirements of the content or activity presented. Groups should be formed for specific purposes and be flexible in composition and short-term in duration.

Teachers should consider the following examples of differentiating the process:

- Offer hands-on activities for students.
- Provide activities and resources that encourage students to further explore a topic of particular interest.
- Use activities in which all learners work with the same learning outcomes but proceed with different levels of support, challenge, or complexity.

Differentiating the Product

Differentiating the product involves varying the complexity and type of product that students create to demonstrate learning outcomes. Teachers provide a variety of opportunities for students to demonstrate and show evidence of what they have learned.

Teachers should give students options to demonstrate their learning (e.g., create an online presentation, write a letter, or develop a mural). This will lead to an increase in student engagement.

Differentiating the Learning Environment

The learning environment includes the physical and the affective tone or atmosphere in which teaching and learning take place, and can include the noise level in the room, whether student activities are static or mobile, or how the room is furnished and arranged. Classrooms may include tables of different shapes and sizes, space for quiet individual work, and areas for collaboration.

Teachers can divide the classroom into sections, create learning centres, or have students work both independently and in groups. The structure should allow students to move from whole group, to small group, pairs, and individual learning experiences and support a variety of ways to engage in learning. Teachers should be sensitive and alert to ways in which the classroom environment supports their ability to interact with students.

Teachers should consider the following examples of differentiating the learning environment:

- Develop routines that allow students to seek help when teachers are with other students and cannot provide immediate attention.
- Ensure there are places in the room for students to work quietly and without distraction, as well as places that invite student collaboration.
- Establish clear guidelines for independent work that match individual needs.
- Provide materials that reflect diversity of student background, interests, and abilities.

The physical learning environment must be structured in such a way that all students can gain access to information and develop confidence and competence.

Meeting the Needs of Students with Exceptionalities

All students have individual learning needs. Some students, however, have exceptionalities (defined by the Department of Education) which impact their learning. The majority of students with exceptionalities access the prescribed curriculum. For details of these exceptionalities see www.gov.nl.ca/edu/k12/studentsupportservices/exceptionalities.html

Supports for these students may include

1. Accommodations
2. Modified Prescribed Courses
3. Alternate Courses
4. Alternate Programs
5. Alternate Curriculum

For further information, see Service Delivery Model for Students with Exceptionalities at www.cdli.ca/sdm/

Classroom teachers should collaborate with instructional resource teachers to select and develop strategies which target specific learning needs.

Meeting the Needs of Students who are Highly Able

(includes gifted and talented)

Some students begin a course or topic with a vast amount of prior experience and knowledge. They may know a large portion of the material before it is presented to the class or be capable of processing it at a rate much faster than their classmates. All students are expected to move forward from their starting point. Many elements of differentiated instruction are useful in addressing the needs of students who are highly able.

Teachers may

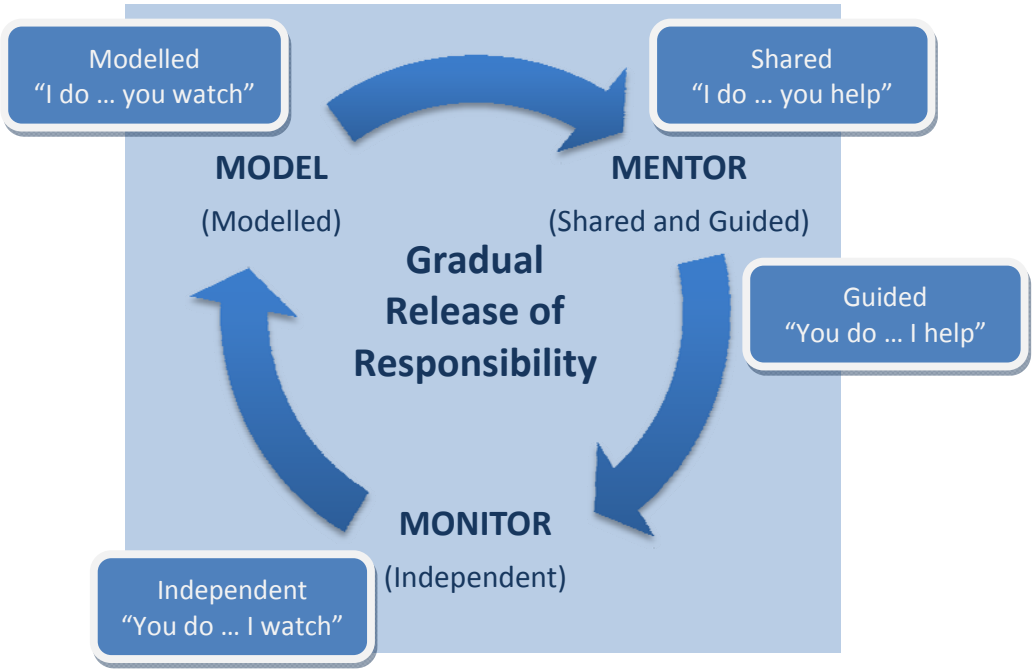
- assign independent study to increase depth of exploration in an area of particular interest;
- compact curriculum to allow for an increased rate of content coverage commensurate with a student's ability or degree of prior knowledge;
- group students with similar abilities to provide the opportunity for students to work with their intellectual peers and elevate discussion and thinking, or delve deeper into a particular topic; and
- tier instruction to pursue a topic to a greater depth or to make connections between various spheres of knowledge.

Highly able students require the opportunity for authentic investigation to become familiar with the tools and practices of the field of study. Authentic audiences and tasks are vital for these learners. Some highly able learners may be identified as gifted and talented in a particular domain. These students may also require supports through the Service Delivery Model for Students with Exceptionalities.

Gradual Release of Responsibility

Teachers must determine when students can work independently and when they require assistance. In an effective learning environment, teachers choose their instructional activities to model and scaffold composition, comprehension, and metacognition that is just beyond the students' independence level. In the gradual release of responsibility approach, students move from a high level of teacher support to independent work. If necessary, the teacher increases the level of support when students need assistance. The goal is to empower students with their own learning strategies, and to know how, when, and why to apply them to support their individual growth. Guided practice supports student independence. As a student demonstrates success, the teacher should gradually decrease his or her support.

Gradual Release of Responsibility Model



Literacy

"Literacy is the ability to identify, understand, interpret, create, communicate and compute, using printed and written materials associated with varying contexts. Literacy involves a continuum of learning in enabling individuals to achieve their goals, to develop their knowledge and potential, and to participate fully in their community and wider society". To be successful, students require a set of interrelated skills, strategies and knowledge in multiple literacies that facilitate their ability to participate fully in a variety of roles and contexts in their lives, in order to explore and interpret the world and communicate meaning. (The Plurality of Literacy and its Implications for Policies and Programmes, 2004, p.13)

Literacy is

- a process of receiving information and making meaning from it; and
- the ability to identify, understand, interpret, communicate, compute, and create text, images, and sounds.

Literacy development is a lifelong learning enterprise beginning at birth that involves many complex concepts and understandings. It is not limited to the ability to read and write; no longer are we exposed only to printed text. It includes the capacity to learn to communicate, read, write, think, explore, and solve problems. Individuals use literacy skills in paper, digital, and live interactions to engage in a variety of activities:

- Analyze critically and solve problems.
- Comprehend and communicate meaning.
- Create a variety of texts.
- Make connections both personally and inter-textually.
- Participate in the socio-cultural world of the community.
- Read and view for enjoyment.
- Respond personally.

These expectations are identified in curriculum documents for specific subject areas as well as in supporting documents, such as *Cross-Curricular Reading Tools* (CAMET).

With modelling, support, and practice, students' thinking and understandings are deepened as they work with engaging content and participate in focused conversations.

Reading in the Content Areas

The focus for reading in the content areas is on teaching strategies for understanding content. Teaching strategies for reading comprehension benefits all students as they develop transferable skills that apply across curriculum areas.

When interacting with different texts, students must read words, view and interpret text features, and navigate through information presented in a variety of ways including, but not limited to

Advertisements	Movies	Poems
Blogs	Music videos	Songs
Books	Online databases	Speeches
Documentaries	Plays	Video games
Magazine articles	Podcasts	Websites

Students should be able to interact with and comprehend different texts at different levels.

There are three levels of text comprehension:

- Independent level – Students are able to read, view, and understand texts without assistance.
- Instructional level – Students are able to read, view, and understand most texts but need assistance to fully comprehend some texts.
- Frustration level – Students are not able to read or view with understanding (i.e., texts may be beyond their current reading level).

Teachers will encounter students working at all reading levels in their classrooms and will need to differentiate instruction to meet their needs. For example, print texts may be presented in audio form, physical movement may be associated with synthesizing new information with prior knowledge, or graphic organizers may be created to present large amounts of print text in a visual manner.

When interacting with information that is unfamiliar to students, it is important for teachers to monitor how effectively students are using strategies to read and view texts:

- Analyze and think critically about information.
- Determine importance to prioritize information.
- Engage in questioning before, during, and after an activity related to a task, text, or problem.
- Make inferences about what is meant but not said.
- Make predictions.
- Synthesize information to create new meaning.
- Visualize ideas and concepts.

Learning Skills for Generation Next

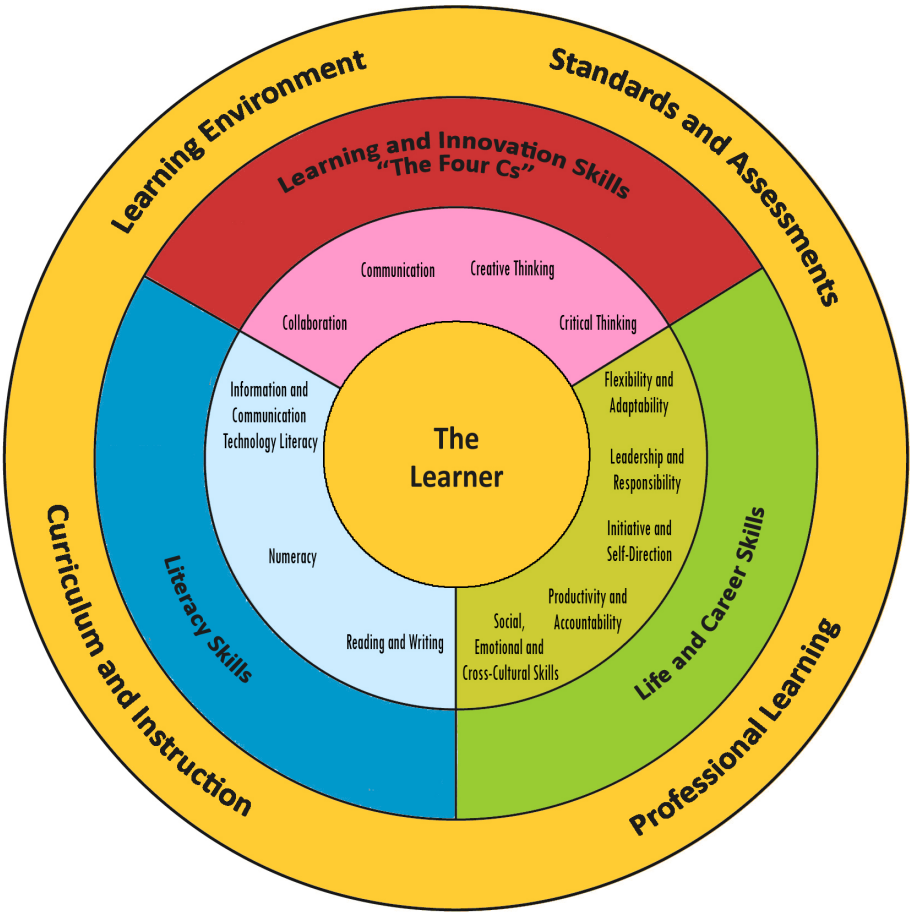
Generation Next is the group of students who have not known a world without personal computers, cell phones, and the Internet. They were born into this technology. They are digital natives.

Students need content and skills to be successful. Education helps students learn content and develop skills needed to be successful in school and in all learning contexts and situations. Effective learning environments and curricula challenge learners to develop and apply key skills within the content areas and across interdisciplinary themes.

Learning Skills for Generation Next encompasses three broad areas:

- Learning and Innovation Skills enhance a person's ability to learn, create new ideas, problem solve, and collaborate.
- Life and Career Skills address leadership, and interpersonal and affective domains.
- Literacy Skills develop reading, writing, and numeracy, and enhance the use of information and communication technology.

The diagram below illustrates the relationship between these areas. A 21st century curriculum employs methods that integrate innovative and research-driven teaching strategies, modern learning technologies, and relevant resources and contexts.



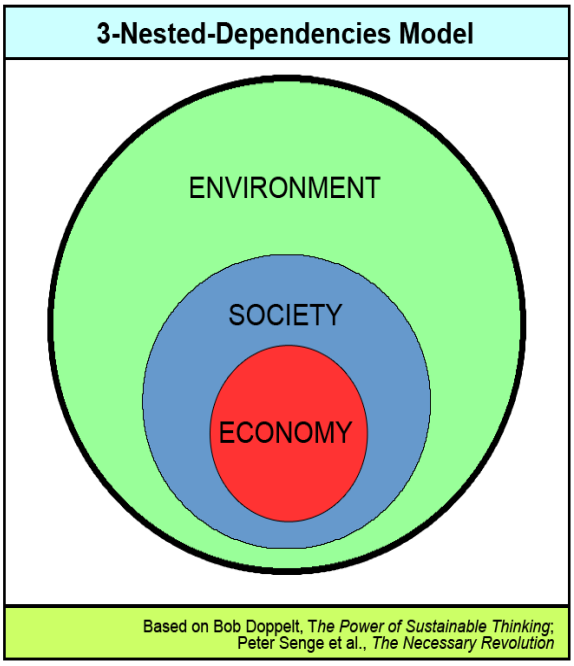
Support for students to develop these abilities and skills is important across curriculum areas and should be integrated into teaching, learning, and assessment strategies. Opportunities for integration of these skills and abilities should be planned with engaging and experiential activities that support the gradual release of responsibility model. For example, lessons in a variety of content areas can be infused with learning skills for Generation Next by using open-ended questioning, role plays, inquiry approaches, self-directed learning, student role rotation, and Internet-based technologies.

All programs have a shared responsibility in developing students' capabilities within all three skill areas.

Education for Sustainable Development

Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". (Our Common Future, 43)

Sustainable development is comprised of three integrally connected areas: economy, society, and environment.



As conceived by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) the overall goal of Education for Sustainable Development (ESD) is to integrate the knowledge, skills, values, and perspectives of sustainable development into all aspects of education and learning. Changes in human behaviour should create a more sustainable future that supports environmental integrity and economic viability, resulting in a just society for all generations.

ESD involves teaching *for* rather than teaching *about* sustainable development. In this way students develop the skills, attitudes, and perspectives to meet their present needs without compromising the ability of future generations to meet their needs.

Within ESD, the knowledge component spans an understanding of the interconnectedness of our political, economic, environmental, and social worlds, to the role of science and technology in the development of societies and their impact on the environment. The skills necessary include being able to assess bias, analyze consequences of choices, ask questions, and solve problems. ESD values and perspectives include an appreciation for the interdependence of all life forms, the importance of individual responsibility and action, an understanding of global issues as well as local issues in a global context. Students need to be aware that every issue has a history, and that many global issues are linked.

Assessment and Evaluation

Assessment

Assessment is the process of gathering information on student learning.

How learning is assessed and evaluated and how results are communicated send clear messages to students and others about what is valued.

Assessment instruments are used to gather information for evaluation. Information gathered through assessment helps teachers determine students' strengths and needs, and guides future instruction.

Teachers are encouraged to be flexible in assessing student learning and to seek diverse ways students might demonstrate what they know and are able to do.

Evaluation involves the weighing of the assessment information against a standard in order to make a judgement about student achievement.

Assessment can be used for different purposes:

1. Assessment *for* learning guides and informs instruction.
2. Assessment *as* learning focuses on what students are doing well, what they are struggling with, where the areas of challenge are, and what to do next.
3. Assessment *of* learning makes judgements about student performance in relation to curriculum outcomes.

1. Assessment for Learning

Assessment *for* learning involves frequent, interactive assessments designed to make student learning visible. This enables teachers to identify learning needs and adjust teaching accordingly. Assessment *for* learning is not about a score or mark; it is an ongoing process of teaching and learning:

- Pre-assessments provide teachers with information about what students already know and can do.
- Self-assessments allow students to set goals for their own learning.
- Assessment *for* learning provides descriptive and specific feedback to students and parents regarding the next stage of learning.
- Data collected during the learning process from a range of tools enables teachers to learn as much as possible about what a student knows and is able to do.

2. Assessment as Learning

Assessment *as* learning involves students' reflecting on their learning and monitoring their own progress. It focuses on the role of the student in developing metacognition and enhances engagement in their own learning. Students can

- analyze their learning in relation to learning outcomes,
- assess themselves and understand how to improve performance,
- consider how they can continue to improve their learning, and
- use information gathered to make adaptations to their learning processes and to develop new understandings.

3. Assessment of Learning

Assessment *of* learning involves strategies designed to confirm what students know in terms of curriculum outcomes. It also assists teachers in determining student proficiency and future learning needs. Assessment *of* learning occurs at the end of a learning experience and contributes directly to reported results. Traditionally, teachers relied on this type of assessment to make judgements about student performance by measuring learning after the fact and then reporting it to others. Used in conjunction with the other assessment processes previously outlined, assessment *of* learning is strengthened. Teachers can

- confirm what students know and can do;
- report evidence to parents/guardians, and other stakeholders, of student achievement in relation to learning outcomes; and
- report on student learning accurately and fairly using evidence obtained from a variety of contexts and sources.

Involving Students in the Assessment Process

Students should know what they are expected to learn as outlined in the specific curriculum outcomes of a course as well as the criteria that will be used to determine the quality of their achievement. This information allows students to make informed choices about the most effective ways to demonstrate what they know and are able to do.

It is important that students participate actively in assessment by co-creating criteria and standards which can be used to make judgements about their own learning. Students may benefit from examining various scoring criteria, rubrics, and student exemplars.

Students are more likely to perceive learning as its own reward when they have opportunities to assess their own progress. Rather than asking teachers, "What do you want?", students should be asking themselves questions:

- What have I learned?
- What can I do now that I couldn't do before?
- What do I need to learn next?

Assessment must provide opportunities for students to reflect on their own progress, evaluate their learning, and set goals for future learning.

Assessment Tools

In planning assessment, teachers should use a broad range of tools to give students multiple opportunities to demonstrate their knowledge, skills, and attitudes. The different levels of achievement or performance may be expressed as written or oral comments, ratings, categorizations, letters, numbers, or as some combination of these forms.

The grade level and the activity being assessed will inform the types of assessment tools teachers will choose:

Anecdotal Records	Photographic Documentation
Audio/Video Clips	Podcasts
Case Studies	Portfolios
Checklists	Presentations
Conferences	Projects
Debates	Questions
Demonstrations	Quizzes
Exemplars	Role Plays
Graphic Organizers	Rubrics
Journals	Self-assessments
Literacy Profiles	Tests
Observations	Wikis

Assessment Guidelines

Assessments should measure what they intend to measure. It is important that students know the purpose, type, and potential marking scheme of an assessment. The following guidelines should be considered:

- Collect evidence of student learning through a variety of methods; do not rely solely on tests and paper and pencil activities.
- Develop a rationale for using a particular assessment of learning at a specific point in time.
- Provide descriptive and individualized feedback to students.
- Provide students with the opportunity to demonstrate the extent and depth of their learning.
- Set clear targets for student success using learning outcomes and assessment criteria.
- Share assessment criteria with students so that they know the expectations.

Evaluation

Evaluation is the process of analyzing, reflecting upon, and summarizing assessment information, and making judgements or decisions based on the information gathered. Evaluation is conducted within the context of the outcomes, which should be clearly understood by learners before teaching and evaluation take place. Students must understand the basis on which they will be evaluated and what teachers expect of them.

During evaluation, the teacher interprets the assessment information, makes judgements about student progress, and makes decisions about student learning programs.

Section Two: Curriculum Design

Rationale

The vision of science education in Newfoundland and Labrador is 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.*

To develop scientific literacy, students require diverse learning experiences which provide opportunities to explore, analyze, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment that will affect their personal lives, careers, and futures.

Science education which strives for scientific literacy must engage students in science inquiry, problem solving, and decision making.

Science Inquiry

Science inquiry involves posing questions and developing explanations for phenomena. While there is general agreement that there is no such thing as “the” scientific method, students require certain skills to participate in the activities of science. Skills such as questioning, observing, inferring, predicting, measuring, hypothesizing, classifying, designing experiments, collecting data, analyzing data, and interpreting data are fundamental to engaging in science. These skills are often represented as a cycle which involves the posing of questions, the generation of possible explanations, and the collection of evidence to determine which of these explanations is most useful in accounting for the phenomenon under investigation. Teachers should engage students in science inquiry activities to develop these skills.

Problem Solving

Problem solving involves seeking solutions to human problems. It may be represented as a cycle consisting of the proposing, creating, and testing of prototypes, products, and techniques in an attempt to reach an optimum solution to a given problem. The skills involved in this cycle facilitate a process which has different aims and procedures from science inquiry. Students should be given opportunities to propose, perform, and evaluate solutions to problem solving or technological tasks.

Decision Making

Decision making involves determining what we should do in a particular context or in response to a given situation. Increasingly, the types of problems that we deal with, both individually and collectively, require an understanding of the processes and products of science and technology. The process of decision making involves identification of the problem or situation, generation of possible solutions or courses of action, evaluation of the alternatives, and a thoughtful decision based on the information available. Students should be actively involved in decision making situations. While important in their own right, decision making situations also provide a relevant context for engaging in science inquiry and/or problem solving.

Curriculum Outcomes Framework

The foundation of the curriculum outcomes framework is the general curriculum outcomes (GCOs). Four general curriculum outcomes have been identified to delineate the four critical aspects of students' scientific literacy: science, technology, society, and the environment (STSE), skills, knowledge, and attitudes. These four GCOs are common to all science courses.

General Curriculum Outcomes

GCO 1: Science, Technology, Society, and the Environment

Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

GCO 2: Skills

Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

GCO 3: Knowledge

Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

GCO 4: Attitudes

Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Key Stage Curriculum Outcomes

Key stage curriculum outcomes (KSCOs) align with the GCOs and summarize what students are expected to know and be able to do by the end of Grade 12.

GCO 1: STSE

By the end of Grade 12, students will be expected to

- describe and explain disciplinary and interdisciplinary processes used to understand natural phenomena and develop technological solutions;
- distinguish between science and technology in terms of their respective goals, products, and values, and describe the development of scientific theories and technologies over time;
- analyze and explain how science and technology interact with and advance one another;
- analyze how individuals, society, and the environment are interdependent with scientific and technological endeavours; and
- evaluate social issues related to the applications and limitations of science and technology, and explain decisions in terms of advantages and disadvantages for sustainability, considering a variety of perspectives.

GCO 2: Skills

By the end of Grade 12, students will be expected to

- ask questions about observed relationships and plan investigations of questions, ideas, problems, and issues;
- conduct investigations into relationships among observable variables, and use a broad range of tools and techniques to gather and record data and information;
- analyze data and apply mathematical and conceptual models to develop and assess possible explanations; and
- work as a member of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results.

GCO 3: Knowledge

By the end of Grade 12, students will be expected to

- compare and contrast the reproduction and development of representative organisms;
- determine how cells use matter and energy to maintain organization necessary for life;
- demonstrate an understanding of the structure and function of genetic materials;
- analyze the patterns and products of evolution;
- compare and contrast mechanisms used by organisms to maintain homoeostasis; and
- evaluate relationships that affect the biodiversity and sustainability of life within the biosphere.

GCO 4: Attitudes

By the end of Grade 12, students will be expected to

- value the role and contributions of science and technology in our understanding of phenomena that are directly observable and those that are not;
- appreciate that the applications of science and technology can raise ethical dilemmas;
- value the contributions to scientific and technological developments made by individuals from many societies and cultural backgrounds;
- show a continuing and more informed curiosity and interest in science and science-related issues;
- acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research;
- consider further studies and careers in science- and technology-related fields;
- confidently evaluate evidence and consider alternative perspectives, ideas, and explanations;
- use factual information and rational explanations when analyzing and evaluating;
- value the processes for drawing conclusions;
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas;
- have a sense of personal and shared responsibility for maintaining a sustainable environment;
- project the personal and shared social, and environmental consequences of proposed action;
- want to take action for maintaining a sustainable environment;
- show concern for safety and accept the need for rules and regulations; and
- be aware of the direct and indirect consequences of their actions.

Specific Curriculum Outcomes

Specific curriculum outcomes (SCOs) align to KSCOs and GCOs and describe what students should know and be able to do at the end of each course. They are intended to serve as the focus for the design of learning experiences and assessment tasks. SCOs are organized into units for each science course.

Course Overview

SCOs for Biology 3201 have been organized into four units:

Unit i: Integrated Skills

Unit 1: Cell Reproduction and the Continuity of Life

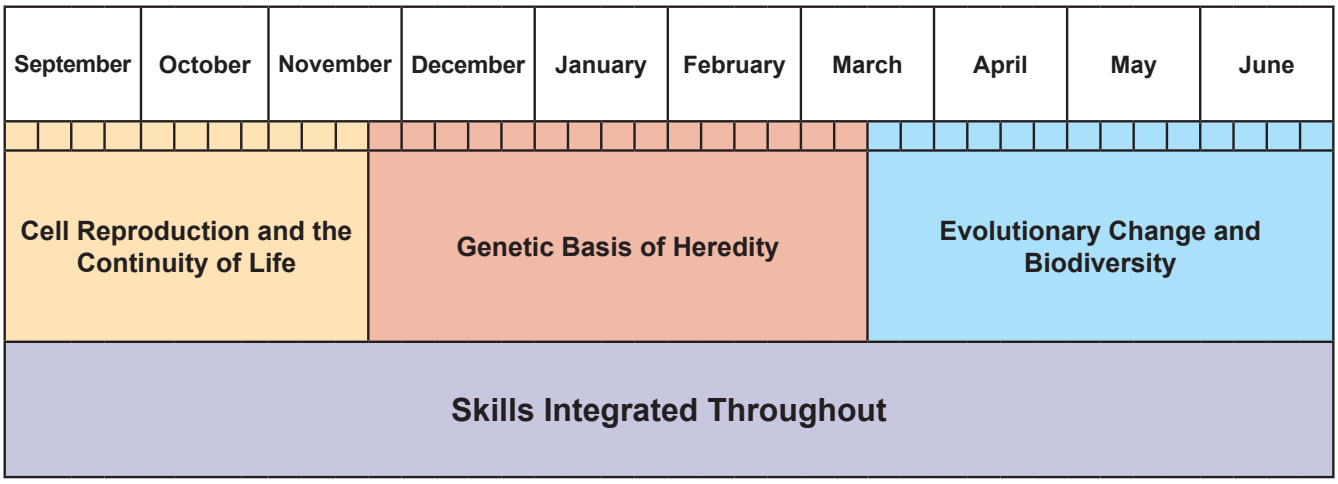
Unit 2: Genetic Basis of Heredity

Unit 3: Evolutionary Change and Biodiversity

Suggested Yearly Plan

The order in which units are presented in the curriculum guide is the recommended sequence.

Note, the Integrated Skills unit (Unit i) is not intended to be taught as a separate, stand alone unit.



How to Use the Four Column Curriculum Layout

Outcomes

Column one contains specific curriculum outcomes (SCO) and accompanying delineations where appropriate. The delineations provide specificity in relation to key ideas.

Outcomes are numbered in ascending order.

Delineations are indented and numbered as a subset of the originating SCO.

All outcomes are related to general curriculum outcomes.

Focus for Learning

Column two is intended to assist teachers with instructional planning. It also provides context and elaboration of the ideas identified in the first column.

This may include

- cautionary notes
- clarity in terms of scope
- common misconceptions
- depth of treatment
- knowledge required to scaffold and challenge student's learning
- references to prior knowledge

SPECIFIC CURRICULUM OUTCOMES

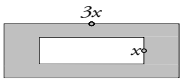
GCO 1: Represent algebraic expressions in multple ways

Outcomes	Focus for Learning
Students will be expected to	
1.0 model, record and explain the operations of multiplication and division of polynomial expressions (limited to polynomials of degree less than or equal to 2) by monomials, concretely, pictorially and symbolically. [GCO 1]	From previous work with number operations, students should be aware that division is the inverse of multiplication. This can be extended to divide polynomials by monomials. The study of division should begin with division of a monomial by a monomial, progress to a polynomial by a scalar, and then to division of a polynomial by any monomial.
1.2 model division of a given polynomial expression by a given monomial concretely or pictorially and record the process symbolically.	Division of a polynomial by a monomial can be visualized using area models with algebra tiles. The most commonly used symbolic method of dividing a polynomial by a monomial at this level is to divide each term of the polynomial by the monomial, and then use the exponent laws to simplify. This method can also be easily modelled using tiles, where students use the sharing model for division.
1.3 apply a personal strategy for multiplication and division of a given polynomial expression	Because there are a variety of methods available to multiply or divide a polynomial by a monomial, students should be given the opportunity to apply their own personal strategies. They should be encouraged to use algebra tiles, area models, rules of exponents, the distributive property and repeated addition, or a combination of any of these methods, to multiply or divide polynomials. Regardless of the method used, students should be encouraged to record their work symbolically. Understanding the different approaches helps students develop flexible thinking.

Sample Performance Indicator

Write an expression for the missing dimensions of each rectangle and determine the area of the walkway in the following problem:

- The inside rectangle in the diagram below is a flower garden. The shaded area is a concrete walkway around it. The area of the flower garden is given by the expression $2x^2 + 4x$ and the area of the large rectangle, including the walkway and the flower garden, is $3x^2 + 6x$.



Sample Performance Indicator(s)

This provides a summative, higher order activity, where the response would serve as a data source to help teachers assess the degree to which the student has achieved the outcome.

Performance indicators are typically presented as a task, which may include an introduction to establish a context. They would be assigned at the end of the teaching period allocated for the outcome.

Performance indicators would be assigned when students have attained a level of competence, with suggestions for teaching and assessment identified in column three.

SPECIFIC CURRICULUM OUTCOMES

GCO 1: Represent algebraic expressions in multple ways

Sample Teaching and Assessment Strategies	**Resources and Notes**
Teachers may use the following activities and/or strategies aligned with the corresponding assessment tasks: Modeling division using the sharing model provides a good transition to the symbolic representation. For example, $\frac{3x+12}{3} = \frac{3x}{3} + \frac{12}{3}$. To model this, students start with a collection of three x-tiles and 12 unit tiles and divide them into three groups.  For this example, $x + 4$ tiles will be a part of each group, so the quotient is $x + 4$. **Activation** Students may • Model division of a polynomial by a monomial by creating a rectangle using four x^2-tiles and eight x-tiles, where $4x$ is one of the dimensions. Teachers may • Ask students what the other dimension is and connect this to the symbolic representation. **Connection** Students may • Model division of polynomials and determine the quotient (i) $(6x^2 + 12x - 3) \div 3$ (ii) $(4x^2 - 12x) \div 4x$ **Consolidation** Students may • Draw a rectangle with an area of $36a^2 + 12a$ and determine as many different dimensions as possible. Teachers may • Discuss why there are so many different possible dimensions. **Extension** Students may • Determine the area of one face of a cube whose surface area is represented by the polynomial $24s^2$. • Determine the length of an edge of the cube.	**Authorized** • *Math Makes Sense 9* • Lesson 5.5: Multiplying and Dividing a Polynomial by a Constant • Lesson 5.6: Multiplying and Dividing a Polynomial by a Monomial • ProGuide: pp. 35-42, 43-51 • CD-ROM: Master 5.23, 5.24 • See It Videos and Animations: • Multiplying and Dividing a Polynomial by a Constant, Dividing • Multiplying and Dividing a Polynomial by a Monomial, Dividing • SB: pp. 241-248, 249-257 • PB: pp. 206-213, 214-219

Resources and Notes

Column four references supplementary information and possible resources for use by teachers.

These references will provide details of resources suggested in column two and column three.

Suggestions for Teaching and Assessment

This column contains specific sample tasks, activities, and strategies that enable students to meet the goals of the SCOs and be successful with performance indicators. Instructional activities are recognized as possible sources of data for assessment purposes. Frequently, appropriate techniques and instruments for assessment purposes are recommended.

Suggestions for instruction and assessment are organized sequentially:

- Activation – suggestions that may be used to activate prior learning and establish a context for the instruction
- Connection – linking new information and experiences to existing knowledge inside or outside the curriculum area
- Consolidation – synthesizing and making new understandings
- Extension – suggestions that go beyond the scope of the outcome

These suggestions provide opportunities for differentiated learning and assessment.

How to use a Strand overview

At the beginning of each strand grouping there is explanation of the focus for the strand and a flow chart identifying the relevant GCOs, KSCOs and SCOs.

GCO 1: Students will be expected to speak and listen to explore, extend, clarify, and reflect on their thoughts, ideas, feelings, and experiences.

Key Stage 9

- examine others' ideas in discussion to extend their own understanding
- ask relevant questions calling for elaboration, clarification, or qualification and respond thoughtfully to such questions
- articulate, advocate, and support points of view, presenting viewpoints in a convincing manner
- listen critically to assess the adequacy of the evidence speakers give to evaluate the integrity of information presented

1.1 recognize that contributions from others are needed to generate and sustain discussions
1.2 ask questions of others about their ideas
1.3 respond to questions to provide clarification and elaboration
1.4 express a point of view and support it with personal examples, explanations, or reasoning
1.5 use active listening skills to identify main ideas and supporting details

GCO 2: Students will be expected to communicate information and ideas effectively and clearly, and to respond personally and critically.

Key Stage 9

- participate constructively in conversation, small-group and whole-group discussion, and debate, using a range of strategies that contribute to effective talk
- adapt vocabulary, sentence structure, and rate of speech to the speaking occasion
- give and follow instructions and respond to complex questions and directions of increasing complexity
- evaluate their own and others' uses of spoken language in a range of contexts, recognizing the effects of significant verbal and non-verbal language features

2.1 practice a range of strategies that contribute to effective talk
2.2 assess the need for clarification or elaboration when responding to instructions or questions
2.3 identify strategies and behaviours associated with effective speaking

GCO 3: Students will be expected to interact with sensitivity and respect, considering the situation, audience, and purpose.

Key Stage 9

- demonstrate active listening and respect for the needs, rights, and feelings of others
- demonstrate an awareness of the power of spoken language to influence and manipulate and to reveal ideas, values, and attitudes
- demonstrate an awareness that spoken language has different conventions in different situations and cultures and use language appropriate to the situation

3.1 demonstrate active speaking and listening skills
3.2 express ideas and opinions in a manner that reflects sensitivity and shows respect to others
3.3 recognize that values and attitudes such as bias, beliefs, and prejudice can be reflected in oral language
3.4 demonstrate an awareness that oral language can be used to influence and manipulate

GCOs

KSCO

SCOs

The SCOs Continuum follows the chart to provide context for teaching and assessment for the grade/course in question. The current grade is highlighted in the chart.

Previous Grade | Current Grade | Next Grade

GCO

GCO 1: Students will be expected to speak and listen to explore, extend, clarify, and reflect on their thoughts, ideas, feelings, and experiences.

SCOs

Grade 6	Grade 7	Grade 8
1.0 examine how sharing experiences, explanations or reasoning with others clarifies and extends thinking	1.1 recognize that contributions from others are needed to generate and sustain discussions	1.1 reflect upon the contribution of others' ideas during discussion
2.0 use active listening strategies for a variety of purposes	1.2 ask questions of others about their ideas	1.2 ask questions of others for clarification
3.0 assess how thinking may be affected as a result of listening to others	1.3 respond to questions to provide clarification and elaboration	1.3 respond to questions to provide accuracy, relevancy, and validity
	1.4 express a point of view and support it with personal examples, explanations, or reasoning	1.4 express a point of view and support it with personal examples and evidence from various sources
	1.5 use active listening skills to identify main ideas and supporting details	1.5 use active listening skills to interpret main ideas and the relevancy of supporting details

Section Three:
Specific Curriculum Outcomes

Unit i: Integrated Skills

Focus

Students use a variety of skills when investigating questions, ideas, problems, and issues. While these skills 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.

The listing of skills is not intended to imply a linear sequence or to identify a single set of skills required in each science investigation. Every investigation has unique features that determine the particular mix and sequence of skills.

Four broad areas of skills are outlined and developed:

- Initiating and Planning - These are the skills of questioning, identifying problems, and developing initial ideas and plans.
- Performing and Recording - These are the skills of carrying out action plans, which involves gathering evidence by observation and, in most cases, manipulating materials and equipment.
- Analyzing and Interpreting - These are the skills of examining information and evidence, of processing and presenting data so that it can be interpreted, and interpreting, evaluating, and applying the results.
- Communication and Teamwork - In science, communication skills are essential at every stage where ideas are being developed, tested, interpreted, debated, and agreed upon. Teamwork skills are also important, since the development and application of science ideas is a collaborative process both in society and in the classroom.

Students should be provided with opportunities to develop and apply these skills in a variety of contexts. Contexts connect to the STSE component of the curriculum by linking to three processes for skills application:

- Science inquiry - seeking answers to questions through experimentation and research.
- Problem solving - seeking solutions to science-related problems by developing and testing prototypes, products, and techniques to meet a given need.
- Decision making - providing information to assist the decision making process.

Unit i - Integrated Skills

Unit i, the *Integrated Skills* unit, appears at the beginning of this curriculum guide. A total of 43 skill outcomes are identified and addressed throughout high school science courses. However, all skills do not appear in each course or content unit. In Biology 3201, students are expected to develop proficiency with respect to 27 different skill outcomes listed in the outcomes framework.

Outcomes Framework

GCO 2 (Skills): Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

Initiating and Planning

1.0 design an experiment identifying and controlling major variables
2.0 state a prediction and a hypothesis based on available evidence and background information
3.0 evaluate and select appropriate instruments for collecting evidence
4.0 develop and implement appropriate sampling procedures

Performing and Recording

5.0 use instruments effectively and accurately for collecting data
6.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data
7.0 use library and electronic research tools to collect information on a given topic
8.0 select and integrate information from various print and electronic sources or from several parts of the same source
9.0 select and use apparatus and materials safely
10.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials

Analyzing and Interpreting

11.0 describe and apply classification systems and nomenclatures used in the sciences
12.0 identify limitations of a given classification system and identify alternative ways of classifying to accommodate anomalies
13.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
14.0 identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit
15.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
16.0 evaluate the relevance, reliability, and adequacy of data and data collection methods
17.0 identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information
18.0 explain how data support or refute the hypothesis or prediction
19.0 identify and correct practical problems in the way a technological device or system functions
20.0 construct and test a prototype of a device or system and troubleshoot problems as they arise
21.0 evaluate a personally designed and constructed device on the basis of criteria they have developed themselves

Communication and Teamwork

22.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
23.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
24.0 identify multiple perspectives that influence a science-related decision or issue
25.0 develop, present, and defend a position or course of action, based on findings
26.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
27.0 evaluate individual and group processes used in planning, problem solving and decision making, and completing a task

SCO Continuum

GCO 2 (Skills): Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

Science 7-9	Science 10-12
• design an experiment and identify major variables	• design an experiment identifying and controlling major variables
• state a prediction and a hypothesis based on background information or an observed pattern of events	• state a prediction and a hypothesis based on available evidence and background information
• select appropriate methods and tools for collecting data and information and for solving problems	• evaluate and select appropriate instruments for collecting evidence
	• develop and implement appropriate sampling procedures
• use instruments effectively and accurately for collecting data	• use instruments effectively and accurately for collecting data
• organize data using a format that is appropriate to the task or experiment	• compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data
• select and integrate information from various print and electronic sources or from several parts of the same source	• use library and electronic research tools to collect information on a given topic • select and integrate information from various print and electronic sources or from several parts of the same source
• use tools and apparatus safely	• select and use apparatus and materials safely
• demonstrate a knowledge of WHMIS standards by using proper techniques for handling and disposing of lab materials	• demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials
• use or construct a classification key	• describe and apply classification systems and nomenclatures used in the sciences • identify limitation of a given classification system and identify alternative ways of classifying to accommodate anomalies
• compile and display data, by hand or computer, in a variety of formats	• compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
• predict the value of a variable by interpolating and extrapolating from graphical data • identify the line of best fit on a scatter plot and interpolate or extrapolate on the line of best fit	• identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit

Science 7-9	Science 10-12
• interpret patterns and trends in data, and infer and explain relationships among the variables	• interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
• identify the strengths and weaknesses of different methods of collecting and displaying data	• evaluate the relevance, reliability, and adequacy of data and data collection methods
• apply given criteria for evaluating evidence and sources of information	• identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information
• state a conclusion, based on experimental data, and explain how evidence gathered supports or refutes the original idea	• explain how data support or refute the hypothesis or prediction
• identify and correct practical problems in the way a prototype or constructed device functions • test the design of a constructed device or system • evaluate designs and prototypes in terms of function, reliability, safety, efficiency, use of materials, and impact on the environment	• identify and correct practical problems in the way a technological device or system functions • construct and test a prototype of a device or system and troubleshoot problems as they arise • evaluate a personally designed and constructed device on the basis of criteria they have developed themselves
• receive, understand, and act on the ideas of others • communicate questions, ideas, intentions, plans, and results, using lists, notes in point form, sentences, data tables, graphs, drawings, oral language, and other means	• communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others • select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
	• identify multiple perspectives that influence a science-related decision or issue
• defend a given position on an issue or problem, based on their findings	• develop, present, and defend a position or course of action, based on findings
• work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise	• work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
• evaluate individual and group processes used in planning, problem solving and decision making, and completing a task	• evaluate individual and group processes used in planning, problem solving and decision making, and completing a task

Suggested Unit Plan

The *Integrated Skills* unit is not intended to be taught as a separate, stand alone unit. Rather, as skill outcomes [GCO 2] are encountered in Units 1-3, teachers should refer to the focus for learning elaborations and teaching and assessment suggestions provided in the *Integrated Skills* unit.

Provide opportunities for students to develop and apply these skills in science inquiry, problem solving, and decision making contexts.

The inclusion of science projects is strongly recommended to address and assess skill outcomes.

<table>
<tr><th colspan="4">September</th><th colspan="4">October</th><th colspan="4">November</th><th colspan="4">December</th><th colspan="4">January</th><th colspan="4">February</th><th colspan="4">March</th><th colspan="4">April</th><th colspan="4">May</th><th colspan="4">June</th></tr>
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<tr><td colspan="12">Cell Reproduction and the Continuity of Life</td><td colspan="12">Genetic Basis of Heredity</td><td colspan="24">Evolutionary Change and Biodiversity</td></tr>
<tr><td colspan="48">Skills Integrated Throughout</td></tr>
</table>

Initiating and Planning

Outcomes	Focus for Learning
Students will be expected to	
1.0 design an experiment identifying and controlling major variables [GCO 2]	When initiating and planning investigations, students should • state and define questions to investigate; • identify dependent, independent, and control variables; • make hypotheses and plan experiments to test them; and • devise detailed procedures that include controls and ensure relevant, reliable, adequate data. Additionally, students should evaluate experimental designs to identify the inquiry question and major variables, and assess whether confounding variables are adequately controlled. SCO 1.0 should be assessed when students personally design and carry out investigations to measure variation in inherited traits within populations. The skill may also be assessed whenever students engage in open inquiry.
2.0 state a prediction and a hypothesis based on available evidence and background information [GCO 2]	Students began stating predictions and hypotheses in Science 4 using an “If..., then...because...” template. Students should recognize that hypotheses are tentative explanations describing a causal relationship. They stem from problems, questions, observations, logic, other hypotheses, and theories. Hypotheses lead to predictions of what will happen under a given set of circumstances (i.e., tests or investigations). Hypotheses can be accepted, rejected, or modified as a result of evidence. Students should recognize that the vast majority of scientific hypotheses fail. They should, however, consider these failed tests as valuable, because something has been learned. In Biology 3201, emphasis is placed on stating predictions and hypotheses based on available evidence and background information. This skill is specifically addressed when students • use and analyze punnet squares and pedigrees depicting inheritance pattens, • investigate the effect of random mating on large populations, and • research characteristics of different taxonomic groups to infer evolutionary relationships. Additionally, the skill may be addressed whenever students engage in scientific investigations (e.g., when designing and carrying out investigations to measure variation in inherited traits within populations).

Initiating and Planning

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Review the role of variables in science inquiry investigations.
- Distinguish between a prediction and a hypothesis.

Connection

Teachers may

- Model stating predictions and hypotheses.
- Provide science inquiry questions and ask students to identify the independent and dependent variables, as well as confounding variables that would need to be controlled.
- Collaboratively design an experiment with students identifying and controlling major variables to model the skill.
- Provide different scenarios and/or data sets and ask students to identify a science inquiry question, make a prediction and hypothesis, and design an experiment to test their hypothesis. Group sharing may follow to compare and discuss experiments.
- Present exemplars of scientific abstracts and scientific papers.

Students may

- View investigations from *NL Biology* and identify the independent, dependent, and control variables and procedures undertaken to ensure fairness.
- Review the procedure section of an experiment and identify major variables and assess whether confounding variables have been adequately controlled.

Consolidation

Teachers may

- Provide questions to investigate and ask students to design experiments identifying and controlling major variables and state predictions and hypotheses.

Students may

- Suggest improvements to the experimental designs of others.
- Design an experiment identifying and controlling major variables for a science project.

Resources and Notes

Authorized

NL Biology
(Online Teaching Centre [OTC])

- Assessment Checklist 1 Designing an Experiment

Initiating and Planning

Outcomes	Focus for Learning
Students will be expected to	
3.0 evaluate and select appropriate instruments for collecting evidence [GCO 2]	When planning investigations, students should evaluate and select appropriate instruments and processes for collecting required data and information. Often, teachers provide the instrument to be used, however, to meet the expectation of this outcome, students must personally evaluate various instruments (analog and digital) and select the most appropriate for the task. Their evaluation should consider the precision and accuracy of the instrument. If measuring seed length, for example, students may evaluate various callipers, rulers, tape measures, and mobile device applications and select the most appropriate tool. This skill is addressed when students design and carry out investigations to measure variation in inherited traits within populations.
4.0 develop and implement appropriate sampling procedures [GCO 2]	Students are expected to develop and implement appropriate sampling procedures and techniques (i.e., determining required sample size, sample selection procedures, measurement techniques, data analysis procedures) when investigating. Sampling procedures significantly impact the quality of data obtained from experiments. In Biology 3201, the skill is specifically addressed when students design and carry out investigations to measure variation in inherited traits within populations. Students should • decide how variation in the selected traits will be measured (i.e., instrument selection, measurement technique, significant digits); • determine the sample size required to draw conclusions; • decide how samples will be randomly selected; • decide how collected data will be compiled and organized; and • adhere to established sampling procedures and techniques to ensure reliability of the data and collection methods. This skill develops gradually over time, as students are exposed to investigations from different disciplines.

Initiating and Planning

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Model evaluating and selecting appropriate instruments to measure human height. Consider meter sticks, construction tape measure, sewing tape measure, trundle wheel, laser distance measure, and mobile device applications.
- Where possible, provide a variety of instruments from which students may choose when collecting evidence. Include both analog and digital instruments.
- Demonstrate the capabilities and limitations of various instruments.
- Discuss the importance of sample size when making inferences about populations.
- Instruct that accurate measurements should include all certain digits and an estimate of the first unknown digit. A centimetre ruler with millimetre gradations, for example, should be read to two decimal places (e.g., 16.73 cm - 16 cm and 7 mm are certain values, the 3 is an estimate).

Students may

- Analyze experimental procedures to describe the sampling procedures used and discuss whether they were appropriate.
- Collaboratively identify potential limitations of specific sampling instruments or procedures.

Consolidation

Teachers may

- Discuss randomized double blind placebo controlled studies as the standard in medical research.

Students may

- Evaluate and select appropriate instruments and develop appropriate sampling procedures when planning an investigation (e.g., open or guided in-class investigations, science fair project).

Resources and Notes

Performing and Recording

Outcomes	Focus for Learning
Students will be expected to	
5.0 use instruments effectively and accurately for collecting data [GCO 2]	When conducting investigations, students should use analog and digital data collection tools and instruments effectively and accurately. Where appropriate, teachers should demonstrate proper techniques for effective use and measurement accuracy of different instruments and discuss potential sources of error caused by improper use. Students should assess the precision and accuracy of each measuring instrument and, when required, calibrate instruments prior to use. When using analog instruments, measurements should be recorded using the correct number of significant digits (i.e., all certain digits plus one estimated digit [Appendix A, p. 138]). This skill is specifically assessed when students design and carry out investigations to measure variation in inherited traits within populations, however, it may be addressed whenever students use instruments to collect data.
6.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data [GCO 2]	Students should compile and organize data when conducting investigations of questions, ideas, problems, and issues. They should select formats (e.g., charts, diagrams, lists, tables, log books, maps, observational journals, digital files) and data treatments (e.g., grouping data, averaging, compiling data sets) appropriate for the task. The most important criteria should be ease of future interpretation and data analysis. This skill is specifically assessed when students design and carry out investigations to measure variation in inherited traits within populations. Their data should be grouped into categories and organized into a table. Tables should be assessed for appropriateness with respect to ease of data interpretation. This skill is further addressed when students analyze inheritance using punnet squares and pedigrees and may be assessed when they investigate the Hardy-Weinberg principle and research characteristics of different taxonomic groups to infer evolutionary relationships .
7.0 use library and electronic research tools to collect information on a given topic [GCO 2] 8.0 select and integrate information from various print and electronic sources or from several parts of the same source [GCO 2]	Students should use a broad range of research tools and techniques to collect information when investigating questions, ideas, problems, and issues. They should • use advanced search techniques and keywords; and • evaluate the validity, reliability, and bias of information and the source. Review relevant acceptable use of library and electronic research tools, practices, and policies. A review of citing, referencing, types of information, sources, and plagiarism may also be necessary. In Biology 3201, these skills should be developed and assessed when students research cancer therapies, sexually transmitted infections, conception prevention technologies, and characteristics of and relationships among different taxonomic groups.

Performing and Recording

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Review research and citing protocol.
- Review appropriate ways to organize data (e.g., formats, significant digits, units) that facilitate future interpretation.
- Invite a representative from Newfoundland and Labrador Public Libraries (NLPL) to provide an overview of NLPL services and databases. Request library cards for students. Alternatively, the teacher librarian may provide an overview of school library and learning commons services.

Students may

- Discuss why Wikipedia™ may not be a reliable source. Discuss the necessity of research reliability and validity.

Connection

Teachers may

- Provide students raw, unorganized data or information from an investigation and ask them to organize it in an appropriate format.

Students may

- Brainstorm alternative ways to compile and organize data or information and discuss their advantages and disadvantages.
- Discuss the difference between a valid source and a reliable source when conducting research (i.e., a reliable source may not necessarily be valid).
- Take and enlarge images of analog scales when measuring to aid in estimating the first unknown digit.

Consolidation

Teachers may

- Allow different student groups to compile and organize data in different ways. Then ask students to compare the utility of the different formats.

Students may

- Use research inquiry to investigate a science-related idea or issue. Ensure use of proper sources and citations including a bibliography.
- Use research inquiry to collect background information (i.e., literature review) for a science project.
- Integrate data and information from a variety of sources when communicating findings of investigations of questions, ideas, problems, or issues.
- Compile and organize data collected as part of a science project.

Resources and Notes

Authorized

NL Biology
(Student resource [SR])

- pp. 714-716

NL Biology (OTC)

- Assessment Checklist 7 Independent Research Skills

Performing and Recording

Outcomes	Focus for Learning
Students will be expected to	
9.0 select and use apparatus and materials safely [GCO 2]	Routinely review safe and appropriate handling and use of apparatus, tools, and materials. Students should have the requisite knowledge to select and use apparatus, tools, and materials safely, including, but not limited to, chemicals, microscopes, and dissection instruments. Students should also effectively use personal protective and safety equipment, as required. This skill should be assessed whenever students use apparatus and materials during investigations (e.g., dissections, microscope investigations, DNA extraction, DNA model construction). Direct observations, checklists, and self and peer assessment may be used.
10.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials [GCO 2]	WHMIS (Workplace Hazardous Materials Information System) was updated in 2015. While students have prior experience with WHMIS standards and techniques, their mastery should be assessed and documented prior to conducting any investigations. Routinely review WHMIS standards and proper techniques for safe handling and disposal of lab materials (e.g., chemicals, fresh and preserved specimens). Ensure that relevant safety data sheets (SDS) are available for student use. Students' proper handling and disposal of materials should be assessed when extracting DNA and when dissecting fresh and preserved plant and animal specimens.
11.0 describe and apply classification systems and nomenclatures used in the sciences [GCO 2] 12.0 identify limitations of a given classification system and identify alternative ways of classifying to accommodate anomalies [GCO 2]	Classification systems and nomenclatures are human constructs that attempt to make sense of the physical world. In Biology 3201, students should describe and apply • the three domain classification system (i.e., Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species); • evolutionary classification systems (i.e., phylogeny); • binomial nomenclature; and • dichotomous keys, field guides, and mobile device applications to identify species. Students should identify the limitations of different classification systems and identification tools used and identify alternative ways of classifying anomalies. Describing and applying nomenclatures includes, but should not be limited to binomial nomenclature. Nomenclatures may be defined broadly to include discipline-related terminology (i.e., reproduction-, genetics-, and evolution-related terminology). This skill may be assessed whenever students describe phenomena using specific terminology.

Performing and Recording

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Describe examples of classification systems and nomenclatures used in biological sciences.

Connection

Teachers may

- Demonstrate safe use of apparatus, tools, and materials. This may be completed on an as needed basis, or can encompass a set of equipment to be used throughout the year. Assessment of student understanding is required.
- Create a print or digital word wall to display discipline-related terminology (i.e., nomenclature).

Students may

- Select and safely set up apparatus to be used in investigations.
- Develop safety signage or safe operating procedure information sheets for lab apparatus, tools and materials.
- Create a personal visual dictionary of discipline-related terminology (i.e., nomenclature).

Consolidation

Teachers may

- Assess students' ability to focus a microscope to high power.
- Assess students' understanding of WHMIS standards and techniques.

Students may

- Brainstorm and describe a non-scientific classification system (i.e., music store organization), identify hard to classify items, and discuss possible alterations to the system to account for the anomalies.

Resources and Notes

Analyzing and Interpreting

Outcomes	Focus for Learning
Students will be expected to	
13.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots [GCO 2]	Students should compile and display data and information from investigations in a variety of formats: • Diagrams are used to symbolically represent information. • Flow charts are used to represent a process. • Tables organize data and information into labelled columns and rows. • Graphs (e.g., bar, histogram, pictograph, line) help visualize relationships in data. • Scatter plots are used to determine the degree of correlation between variables. Students should select the most appropriate format to represent their data and information and, where possible, use digital technologies in their creation. Representations should be clear, concise, and include titles, headings, labels, scales, units, symbols, and numbers, where appropriate. Accurate representation of data and information is paramount to facilitate analysis and interpretation, identify patterns and trends, and infer or calculate relationships among variables (See Appendix A, pp. 140-142). This skill should be addressed throughout the course and is specifically assessed when students create • diagrams to represent cells undergoing mitotic division, • graphs to analyze reproductive blood hormone data, • data tables to demonstrate and test for genetic equilibrium, • tables to compare characteristics of different taxonomic groups and make hypotheses about evolutionary relationships, and • evolutionary trees to represent hypothesized relationships.
14.0 identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit [GCO 2]	Students have experience, from previous science courses, identifying a line of best fit and interpolating or extrapolating based on that line. A line or curve of best fit represents the trend in data. Students should make the smoothest curve possible, evenly balancing points that do not fit the curve above and below. Where a point is far off the line, an error may have been made. A dotted line should be used when extending the curve beyond the data set. Interpolation is the process of estimating values between points within the data set. Extrapolation is estimating values beyond the limits of the data set. There is some risk of inaccuracy involved with both processes, because it is assumed that the trend continues between or beyond measured data points. This skill should be assessed when students analyze blood hormone data to infer physiological events in reproductive systems. It may, however, be addressed and assessed whenever students analyze graphs.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Review appropriate use of diagrams, flow charts, tables, bar graphs, line graphs, and scatter plots.
- Review how to draw a line of best fit on scatter plots and how to interpolate or extrapolate values based on the line.
- Set clear expectations for the construction of diagrams, tables, graphs, and scatter plots.
- Highlight and discuss common graphing errors (e.g., selecting inappropriate type of graph for the data, placing variables on wrong axes, inappropriate scaling, attempting to have the line of best fit go through all data points).

Students may

- Justify selection of a particular format to compile and display data from an investigation.
- Draw lines of best fit by hand and using digital technologies.

Consolidation

Teachers may

- Provide data compiled and organized from an investigation. Ask students to display the data in an appropriate format.
- Present students with scatter plots and ask them to identify the line of best fit and estimate values using interpolation and extrapolation.
- Present graphs and ask students to explain what the graph is communicating and interpolate and extrapolate information.

Students may

- Draw a line of best fit by hand and compare with one generated using a digital tool, for the same data set.
- Compile and display data and information from class investigations and science projects using a variety of digital technologies.

Resources and Notes

Authorized

NL Biology (SR)

- p. 727

Analyzing and Interpreting

Outcomes	Focus for Learning
Students will be expected to	
15.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables [GCO 2]	Students should analyze data and apply mathematical models to develop and assess possible explanations. This includes interpreting trends and patterns, and inferring or calculating relationships. Patterns refer to data that repeat in a predictable way. A trend is the general tendency of a data set to change. While individual data points may vary, the overall data trend in one direction. Relationships are similar to trends, but have a clear mathematical relationship (e.g., linear relationship). Identifying trends, patterns, and relationships requires accurate representation of data in diagrams, tables, graphs, and scatter plots. This skill should be assessed when students analyze blood hormone data, punnet squares and pedigrees, data supporting natural selection, and data from investigations of the Hardy-Weinberg principle, however, it may also be assessed whenever students analyze and interpret data. Where possible, computers and digital tools should be used to enhance data analysis and interpretation. Note, students should be cautioned about interpretations and inferences based on inadequate sample sizes.
16.0 evaluate the relevance, reliability, and adequacy of data and data collection methods [GCO 2]	Students should evaluate data and data collection methods with respect to • relevance (i.e., Does the collected data help answer the initial question?); • reliability (i.e., Is the data consistent? Can the data be replicated under consistent conditions ?); and • adequacy (i.e., Is the quality and quantity of the data sufficient to draw a conclusion? Is there bias?). Students should recognize that use of inappropriate data collection methods, sampling procedures, and measurement instruments may result in irrelevant, unreliable, or inadequate evidence. They should suggest modifications to investigations to improve the data and data collection methods. This skill is specifically assessed when students design and carry out investigations to measure variation in inherited traits within populations. When investigating, they should recognize outliers in data and provide explanations for their exclusion from data analysis.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Present exemplars of tables and graphs illustrating typical trends and patterns in data, and linear and non-linear relationships.
- Model interpreting patterns and trends in data and inferring or calculating linear and non-linear relationships among variables.
- Review what is meant by relevance, reliability, and adequacy of data and data collection methods and provide examples of irrelevant, unreliable, and inadequate data and methods.
- Present published scientific papers and collaboratively evaluate the data and data collection methods.
- Discuss outliers and rationale for their exclusion from data analysis.

Students may

- Review scientific papers and lab reports of peers and evaluate data and data collection methods for relevance, reliability and adequacy.

Consolidation

Teachers may

- Present graphs and ask students to
  - explain what the graph is communicating,
  - interpolate and extrapolate information,
  - identify patterns or trends,
  - infer relationships among variables, and
  - calculate, where possible, linear and non-linear relationships.

Students may

- Interpret patterns and trends, and infer and calculate relationships in data compiled and displayed as part of class investigations and science projects.

Resources and Notes

Analyzing and Interpreting

Outcomes	Focus for Learning
Students will be expected to	
17.0 identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information [GCO 2]	Science is evidence-based. Students should consider whether evidence is relevant, plausible, sufficient, and reliable. Is there bias? Can the evidence be replicated? Similarly, students should critically evaluate the reliability of sources of information. If the information source is scholarly, they should consider: • Can the information be verified by other scholarly literature? • Has the content been peer-reviewed or edited by a publisher? • Is the information supported by evidence which is referenced? If the information source is non-scholarly, they should consider: • Is the work biased? • Is the work sponsored by a company or special interest group? • What is the purpose of the work? Why was it written? Who is the audience? What is the message? • Who is the author? What are their credentials? Are their credentials visible? Are they affiliated with a recognized research institution? Students should also apply this skill to evaluate scientific research.
18.0 explain how data support or refute the hypothesis or prediction [GCO 2]	Analysis and interpretation of data should culminate in a statement explaining the results of the investigation. This conclusion should refer back to the initial hypothesis and explain whether the results support, partially support, or refute the hypothesis. Additionally, the conclusion should • examine and comment on sources of error and uncertainty, • assess the effectiveness of the investigative design, • suggest applications of findings, and • propose new questions to investigate. This skill is specifically assessed when students investigate the Hardy-Weinberg principle, however, it may be addressed whenever students make hypotheses and predictions as part of investigations.
19.0 identify and correct practical problems in the way a technological device or system functions [GCO 2]	The ability to identify and solve problems is a critical learning skill. In Biology 3201, students use various technological devices when investigating. Invariably, they will identify practical problems with the way a device functions. In these situations, students should attempt to correct the problem. This skill should be assessed when students use microscopes, however, it may also be assessed whenever students use technological devices, including analog and digital devices.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Provide detailed criteria for evaluating evidence and sources of information.
- Discuss the reliability of science-related claims found in advertising and social media.
- Present science-related articles obtained from various information sources (e.g., journals, science magazines, websites, social media) and ask students to apply criteria to evaluate the reliability of the information.
- Discuss how evidence may support or refute the hypothesis, suggest revision of the initial hypothesis, or suggest a new research question.
- Model, with the use of exemplars, how the interpretation of evidence may support or refute a hypothesis.

Students may

- Brainstorm possible sources of science information.
- Discuss the pros and cons of various media for communicating scientific findings.

Consolidation

Teachers may

- Present experimental data and ask students to analyze the data and explain whether it supports or refutes the hypothesis.
- Require students to explain how their data supports or refutes their hypothesis or prediction as part of the discussion section of lab reports.

Students may

- Analyze and interpret collected evidence from investigations to determine whether it supports or refutes the hypothesis and provide an explanation in the discussion section of a lab report.

Resources and Notes

Authorized

NL Biology (SR)

- p. 724

Analyzing and Interpreting

Outcomes	Focus for Learning
Students will be expected to	
20.0 construct and test a prototype of a device or system and troubleshoot problems as they arise [GCO 2]	Science starts with a question. Engineering starts with a problem. Students have used engineering design (i.e., problem solving) processes in previous science and intermediate technology courses, however, review of a typical process is warranted. This skill should be assessed when students personally design and construct a working model of a short DNA strand. They should • clearly define the problem to solve (e.g., constraints, success criteria); • brainstorm or research possible solutions to the problem; • evaluate potential tools and material for use; • evaluate the strengths and weaknesses of possible solutions, collaboratively select a preferred solution, and construct a prototype; • test and evaluate the prototype (testing may result in an unpromising solution being abandoned in favour of trying a different possible solution); • modify the prototype for improvement and retest, iteratively, until a final solution is reached; and • communicate the process followed and the final solution. Troubleshooting problems as they arise and finding solutions is an integral part of the engineering design process.
21.0 evaluate a personally designed and constructed device on the basis of criteria they have developed themselves [GCO 2]	In Science 7-9, students evaluated designs and prototypes in terms of function, reliability, safety, efficiency, use of materials, and impact on the environment. In Biology 3201, they should evaluate devices on the basis of criteria they have personally or collaboratively developed. Criteria should relate to function, attributes, and specifications, based on user identified need. The importance of these criteria can not be understated as they control the design of the device throughout the engineering design process. Developing criteria may also include prioritizing criteria. This skill outcome should be assessed when students personally design and construct a working model of a short DNA strand.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Engage students in quick design challenges to review the engineering design process.
- Present multiple representations of the engineering design processes for comparison and analysis.
- Provide a variety of tools and materials for student selection and use in constructing prototypes.
- Remind students that designing technology includes both products and processes.

Students may

- Recount prior experiences engaging in engineering design processes to construct prototypes.
- Brainstorm and prioritize design criteria for constructed devices.
- Conduct focus groups to determine user criteria for a constructed device.
- Pitch their personal solution to a design problem using sketches to communicate their ideas.
- Keep detailed records of prototypes, construction plans, testing, and design modifications.

Consolidation

Students may

- Present final constructed devices with design criteria to peers for evaluation. Evaluations should include suggestions for improvement.
- Share problems encountered during the design process and how they were solved.

Resources and Notes

Authorized

NL Biology (OTC)

- Assessment Checklist 9 Developing Models

Communication and Teamwork

Outcomes	Focus for Learning
Students will be expected to	
22.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others [GCO 2]	Scientists work in collaborative environments, surrounded by students and other scientists. They share ideas, help each other design experiments and studies, and sharpen each other's conclusions. Effective communication is critical to success. Students should • attentively receive and interpret the ideas of others; • effectively communicate their questions, ideas, and intentions, using appropriate scientific terminology; • evaluate ideas, lending them support or constructive criticism; and • suspend judgement and respond to the ideas of others by asking clarifying questions to ensure understanding. Effectively sending and receiving information is an important learning skill. Communication skills should continue to be developed in all subject areas through a range of activities and strategies. This outcome should be assessed when students • design and carry out investigations to measure variation in inherited traits within populations, • investigate the anatomy and physiology of representative organisms, and • use dichotomous keys, field guides, and mobile device applications to identify specimens. The skill, however, may be assessed whenever students communicate.
23.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results [GCO 2]	Effective science communication requires students to appropriately select and use numbers, symbols, diagrams, charts, tables, graphs, and oral and written language to communicate ideas, plans, and results. Students should use appropriate modes of representation to communicate when asking questions, planning and conducting investigations, using tools and techniques, analyzing data and applying models, evaluating results, and collaborating with peers. This skill should be assessed when students investigate and test the Hardy -Weinberg principle, however, it may also be assessed whenever students communicate their ideas, plans, and results. Assessment should emphasize appropriate, accurate, and effective use of numbers, symbols, graphs, and oral and written language.

Communication and Teamwork

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Encourage students to think aloud, orally communicating their questions, ideas, and intentions when conducting investigations.
- Request students digitally record their group communication when conducting investigations. Recordings may be used for assessment of students' communication skills.
- Use checklists to assess student use of scientific terminology when investigating.
- Provide guidelines for creating formal lab reports.
- Review how to effectively communicate findings using diagrams, flow charts, tables and graphs.
- Provide opportunities for student groups to communicate the findings of investigations in formats of their choosing. Then, compare and discuss the effectiveness of the different formats.
- Require students to use digital technologies when communicating their questions, ideas, plans, and results.

Students may

- Brainstorm ideas related to what effective science communication looks and sounds like.
- Consider the pros and cons of representing a set of data using a table or a graph.
- Analyze scientific papers to become familiar with the modes of representations used in science to communicate research results.

Consolidation

Teachers may

- Assess effective science communication (i.e., use appropriate numeric, symbolic, graphical, and linguistic modes of representation) in formal lab reports.

Students may

- Use appropriate modes of representation to communicate ideas, plans, and results of in-class investigations and science projects.

Resources and Notes

Communication and Teamwork

Outcomes	Focus for Learning
Students will be expected to	
24.0 identify multiple perspectives that influence a science-related decision or issue [GCO 2]	Individuals may have strong feelings about social, environmental, and ethical issues that influence their decisions and actions. When analyzing decisions or issues, students should identify the perspectives of stakeholders (i.e., How do they define the issue?, What assumptions do they make?, What are their values?). Understanding multiple perspectives is an essential component of effective communication and collaboration within problem solving and decision making processes. This skill is specifically addressed when students assess decisions and issues arising from prenatal screening and may be assessed when researching conception prevention technologies.
25.0 develop, present, and defend a position or course of action, based on findings [GCO 2]	Developing and deciding on a preferred solution or position often requires persuading others with differing perspectives. Students should develop a position with respect to social, environmental, and ethical issues associated with applications of genetic technology (e.g., human gene therapy, genetically modified foods, personal genomics) and present and defend their position or course of action. This could be facilitated through debate, role play, or formal presentations with follow up question and answer sessions. Reproductive technologies provide another context for assessment.
26.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise [GCO 2] 27.0 evaluate individual and group processes used in planning, problem solving and decision making, and completing a task [GCO 2]	Students should work collaboratively in science contexts. They should, for example, • communicate effectively, listen, and respond appropriately; • provide and accept constructive criticism; • seek other points of view and consider multiple perspectives; • suspend personal views and objectively evaluate other's ideas; • use procedures that enable everyone to participate; and • willingly work with others and accept assigned roles. When collaborating, students should reflect on and evaluate individual and group processes used. How did the group, for example, • address conflict or differences of opinion; • assign roles and responsibilities; • enable everyone to participate in making decisions; • ensure equal participation of all individuals and value their individual contributions; • ensure individuals took responsibility for assigned tasks, errors made, and difficulties encountered; and • ensure respectful communication. Students should consider how their plan, solution, or decision might have been influenced by these processes. They should identify processes and procedures that proved helpful and make suggestions to improve task completion for future collaborative activities. These skills should be assessed whenever students work together in pairs or small groups.

Communication and Teamwork

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Organize students in pairs and small groups, where possible, to investigate problems, issues, and decisions.

Students may

- Share past experiences related to cooperative group work and collaboratively develop a set of group norms.

Connection

Teachers may

- Discuss the multiple perspectives that have influenced the historical acceptance of concepts and ideas in biology.
- Predetermine roles and responsibilities for groups to assign when carrying out tasks (e.g., manager/facilitator, recorder, presenter, questioner).

Students may

- Brainstorm possible stakeholders and their perspectives when considering science-related decisions or issues.
- View cooperative and collaborative group rubrics and create a list of essential characteristics.
- Collaboratively develop a rubric to assess cooperation and adherence to group norms.

Consolidation

Students may

- Use various sources to develop arguments in support of a position or course of action related to a decision or issue.
- Adopt a specific stakeholder perspective and debate science-related decisions and issues with peers.
- Self and peer evaluate cooperation in science contexts when developing and carrying out plans and troubleshooting problems. Suggest processes and procedures that might improve future collaboration.

Resources and Notes

Authorized

NL Biology (OTC)

- Assessment Checklist 3 Performance Task Self Assessment
- Assessment Checklist 4 Performance Task Group Assessment
- Assessment Checklist 5 Learning Skills
- Assessment Checklist 8 Oral Presentation Skills

Section Three:
Specific Curriculum Outcomes

Unit 1: Cell Reproduction and the Continuity of Life

Focus

Reproduction is an essential process for all living things. In addition to understanding some principles of how living organisms reproduce, students begin to appreciate the complexity and impact of reproductive technologies. Analysis, from a variety of perspectives, of the risks and benefits of these technologies creates opportunities for students to apply scientific knowledge, skills, and attitudes in meaningful situations.

This unit has a strong STSE focus that emphasizes the social and environmental contexts of science and technology and the unifying concepts of constancy and change.

Outcomes Framework

GCO 1 (STSE): Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

29.0 distinguish between scientific questions and technological problems
30.0 describe and evaluate the design of technological solutions and the way they function, using scientific principles
33.0 analyze natural systems to interpret and explain their structure and dynamics
37.0 identify examples where technologies were developed based on scientific understanding
39.0 construct arguments to support a decision or judgement, using examples and evidence and recognizing various perspectives
40.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology
41.0 debate the merits of funding specific scientific or technological endeavours and not others
42.0 analyze society's influence on scientific and technological endeavours
43.0 identify and describe science- and technology-based careers related to the science they are studying

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

28.0 examine the process of cell division and its significance
31.0 evaluate the consequences of medical treatments
32.0 analyze and explain reproductive strategies among living organisms
34.0 analyze and describe the structure and function of human male and female reproductive systems
35.0 explain the human reproductive cycle
36.0 describe the process of human development from fertilization to birth
38.0 evaluate and describe reproductive technologies

GCO 2 (Skills): Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

7.0 use library and electronic research tools to collect information on a given topic
8.0 select and integrate information from various print and electronic sources or from several parts of the same source
9.0 select and use apparatus and materials safely
13.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
14.0 identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit
15.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
17.0 identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information
19.0 identify and correct practical problems in the way a technological device or system functions
24.0 identify multiple perspectives that influence a science-related decision or issue
26.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise

GCO 4 (Attitudes): Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Students are encouraged to

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- appreciate that applications of science and technology can raise ethical dilemmas
- show a continuing and more informed curiosity and interest in science and science-related issues
- acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research
- consider further studies and careers in science- and technology-related fields
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas
- show concern for safety and accept the need for rules and regulations
- be aware of the direct and indirect consequences of their actions

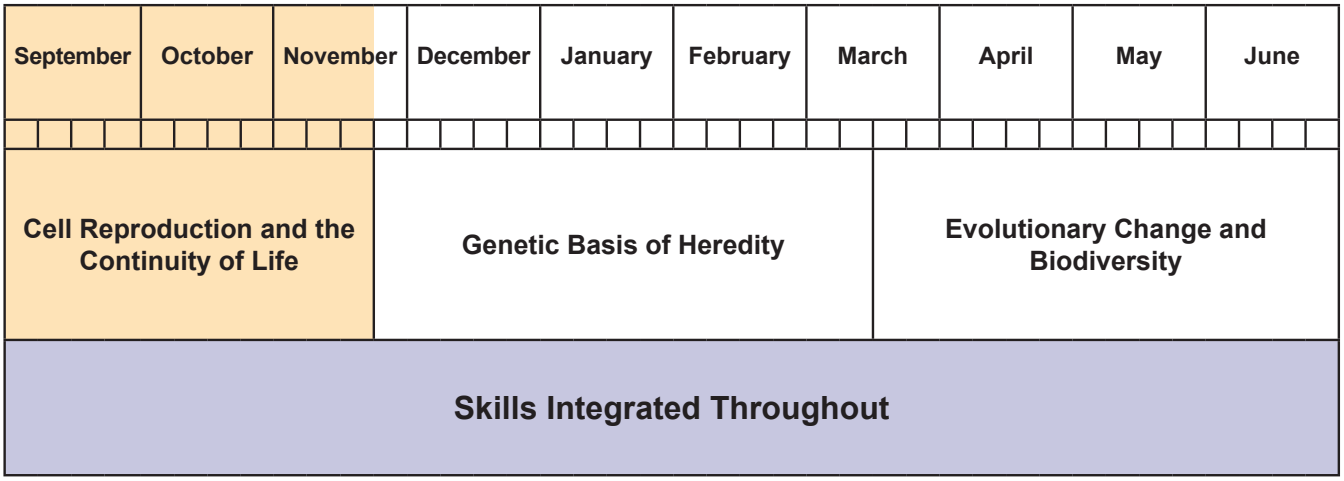
SCO Continuum

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

Science 9	Biology 2201	Biology 3201
Reproduction	*Maintaining Homeostasis*	*Cell Reproduction and the Continuity of Life*
• illustrate and describe the basic process of cell division, including what happens to the cell membrane and the contents of the nucleus. • explain signs of pregnancy and describe the major stages of human development from conception to early infancy • recognize that the cell nucleus contains genetic information and determines cellular processes. • distinguish between sexual and asexual reproduction in representative organisms. • compare sexual and asexual reproduction in terms of their advantages and disadvantages • compare the structure and function of the human reproductive systems • discuss factors that may lead to changes in a cell's genetic information	• explain how systems help maintain homeostasis • analyze homeostatic phenomena to identify the feedback mechanisms involved • explain how tropisms help to maintain homeostasis • analyze the impact of factors on the homeostasis of the nervous system • evaluate the impact of disorders and diseases on homeostasis • explain the importance of fitness to the maintenance of homeostasis • describe the impact of environmental factors on homeostasis • explain the role of enzymes in metabolism • explain the importance of nutrition to the maintenance of homeostasis	• examine the process of cell division and its significance • evaluate the consequences of medical treatments • analyze and explain reproductive strategies among living organisms • analyze and describe the structure and function of human male and female reproductive systems • explain the human reproductive cycle • describe the process of human development from fertilization to birth • evaluate and describe reproductive technologies

Suggested Unit Plan

The *Cell Reproduction and the Continuity of Life* unit is positioned at the beginning of Biology 3201. Knowledge outcomes addressed in this unit are prerequisite to understanding concepts in the G*enetic Basis of Heredity* and *Evolutionary Change and Biodiversity* units.



Somatic Cell Reproduction

Outcomes	Focus for Learning
Students will be expected to	
28.0 examine the process of cell division and its significance [GCO 3] 28.1 describe and explain the process of mitosis	Assess students' microscopy skills and prior knowledge of cell structures and the process of cell division. In Biology 3201, students should • describe how genetic material is organized within the nucleus of eukaryotic cells (i.e., deoxyribonucleic acid [DNA], chromatin, chromosome, autosome, sex chromosome); • explain the significance of chromosome number in somatic cells; • describe the stages of the cell cycle (i.e., interphase [G1, S, G2], mitosis, cytokinesis); • describe the functions of mitosis and cytokinesis (i.e., growth, maintenance, repair); • identify and describe the mitotic phases (i.e., prophase, metaphase, anaphase, telophase); • describe differences in cytokinesis for plant and animal cells; and • describe somatic cell division using specific terminology (i.e., chromosome, chromatin, sister chromatids, diploid, gene, allele, centrioles, spindle fibers, nuclear membrane, centromere, cleavage, cell plate).
9.0 select and use apparatus and materials safely [GCO 2] 13.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots [GCO 2] 19.0 identify and correct practical problems in the way a technological device or system functions [GCO 2]	Students are expected to use microscopy to investigate cells undergoing mitotic division (e.g., onion root-tip cells, white fish embryo cells). As part of this investigation, they should • safely handle the microscope and microscope slides; • focus the microscope using low-, medium-, and high-power (Appendix C, *NL Biology,* p. 722); • view prepared slides and identify cells in interphase, cells in different stages of mitosis, and cells undergoing cytokinesis; and • create biological drawings of cells in different stages of mitosis (Appendix D, *NL Biology*, p. 727). Investigation 12.C (*NL Biology*, p. 471) provides a suggested procedure, however, teachers may choose to defer this investigation until meiosis is addressed. Assess skill outcomes 9.0, 13.0, and 19.0. SCO 13.0 relates to students' use of techniques to produce clear, concise biological drawings (e.g., using stippling to indicate darker areas, double lines to indicate thickness, carefully labelling structures, titling the drawing, indicating magnification in parentheses). Teachers may also to assess SCOs 26.0 and 27.0 at this time. Refer to the *Integrated Skills* unit for elaboration of these outcomes. **Sample Performance Indicators** 1. Use a microscope to view a prepared slide of white fish embryos or onion root-tip cells. Locate a cell undergoing division and identify the mitotic phase. 2. Orally describe the phases of mitosis while manipulating a physical model.

Somatic Cell Reproduction

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Identify human examples of growth, maintenance, and repair and relate to cell division (e.g., a cut finger, sunburn that blisters).
- Facilitate the cell division launch lab (*NL Biology*, p. 453) to review that during cell division, the parent cell divides to produce two new daughter cells that contain the same genetic information.

Connection

Teachers may

- Create a class word wall of unit terminology.
- Present videos and/or animations, sourced online, of cells undergoing division.
- As part of the mitotic division lab, ask students to count or estimate the number of cells visible in interphase and the different phases of mitosis and use their data to estimate the time cells spend in various mitotic stages.

Students may

- Create a personal visual dictionary (print or digital) of unit terminology.
- Use physical models (e.g., coloured beads that snap together, coloured paper clips) to simulate the behaviour of chromosomes during mitosis.
- Use personal mobile devices, in conjunction with microscopes, to capture images of cells undergoing division. Biological drawings may be produced from these images.

Consolidation

Teachers may

- Assess knowledge and skill SCOs as part of a lab station test.

Students may

- Create annotated illustrations of mitotic phases.
- Design and create a foldable to communicate the processes of cell division.
- Create a model of a cell that undergoes mitosis.

Extension

Students may

- Investigate current research on telomeres.

Resources and Notes

Authorized

NL Biology
(Teacher Resource [TR])

- Unit 4 pp. 1-8

NL Biology
(Student Resource [SR])

- pp. 152-171
- pp. 448-461, 471
- pp. 722-727

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Mitosis resources
- Microscopy resources
- Science supply companies

Notes

The magnifying glass icon is used throughout the unit to indicate investigations.

Cancer and the Cell Cycle

Outcomes

Students will be expected to

28.0 examine the process of cell division and its significance [GCO 3]

28.2 explain the relationship between the cell cycle and cancer

29.0 distinguish between scientific questions and technological problems [GCO 1]

30.0 describe and evaluate the design of technological solutions and the way they function, using scientific principles [GCO 1]

31.0 evaluate the consequences of medical treatments [GCO 3]

7.0 use library and electronic research tools to collect information on a given topic [GCO 2]

8.0 select and integrate information from various print and electronic sources or from several parts of the same source [GCO 2]

26.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise [GCO 2]

Focus for Learning

Treatment of SCO 28.0 should include the occurrence of uncontrolled cell division, resulting in the development of cancer. Students should identify and define mutations (i.e., permanent change to a cell's DNA) as the cause of cancer.

This topic provides a context to distinguish scientific questions from technological problems. Determining how regulation of the cell cycle relates to the development of cancer is a scientific question. Developing therapies (i.e., technological products and processes) to target cancer cells and cell cycle regulation is a technological problem.

Students are expected to develop and carry out a plan, in collaborative groups, to research cancer therapies, including, but not limited to, surgery, radiation therapy, chemotherapy, immunotherapy, targeted therapy, hormone therapy, and stem cell transplants. Research findings, for each therapy, should include

- a description of the therapy,
- an explanation of how it functions,
- clinical situations where it is used, and
- common side effects.

As part of this research investigation, SCOs 7.0, 8.0, and 26.0 should be assessed. Teachers may also assess SCOs 17.0 and 27.0 at this time. Refer to the *Integrated Skills* unit for elaboration of these skill outcomes.

As therapies improve and new ones are developed, the range of treatment options available to patients broadens. Students should discuss how personal values and therapeutic outcomes may influence the treatment decisions of patients and medical professionals.

Note, exercise sensitivity when addressing cancers. Some students may have firsthand experience with these diseases.

Attitude

Encourage students to work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas. [GCO 4]

Sample Performance Indicator

Select one type of cancer therapy. Create a newspaper front page to creatively communicate a description of the therapy, an explanation of how it functions, clinical situations where it is used, and common side effects.

Cancer and the Cell Cycle

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Present articles related to cancer therapies for students to read and formulate a response.
- Discuss possible sources of information on cancer therapies and the importance of evaluating sources for credibility and reliability.
- Review citation and reference guidelines.
- Use a cooperative jigsaw activity to facilitate research into cancer therapies.
- Discuss patient use of alternative therapies for cancer treatment (e.g., acupuncture, aromatherapy, art/music therapy, biofeedback, chiropractic/massage therapy, indigenous traditional healing).

Consolidation

Students may

- Create an informational video or pamphlet to explain various cancer therapies to patients.
- Create a digital presentation to communicate findings of their collaborative research.
- Explore current trends in cancer treatment.

Extension

Students may

- Investigate topics of personal interest related to cancer and cancer therapies.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 4 p. 8

NL Biology (SR)

- p. 462

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Cancer-related resources

Formation of Reproductive Cells

Outcomes

Students will be expected to

28.0 examine the process of cell division and its significance [GCO 3]

28.3 describe and explain the process of meiosis

28.4 describe and compare the processes of spermatogenesis and oogenesis

Focus for Learning

Students should

- recognize that meiosis occurs in germ cells;
- explain the significance of chromosome number in gametes;
- identify and describe the phases of meiosis I and II;
- describe gametic cell division using specific terminology (i.e., gamete, haploid, homologous chromosomes, non-sister chromatids, synapsis, tetrad);
- describe the ways in which meiosis contributes to genetic variation (i.e., reduction division, independent assortment, crossing over);
- compare the processes of mitosis and meiosis (i.e., cell type, number of chromosomes, number of daughter cells, and genetic variation);
- describe and compare the processes of oogenesis and spermatogenesis using specific terminology (i.e., spermatogonium, sperm, oogonium, primary oocyte, polar bodies, ova); and
- compare sperm and egg (i.e., physical structure, size, energy reserves, mitochondria, number produced, motility).

Attitude

Encourage students to value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not. [GCO 4]

Sample Performance Indicators

1. Compare anaphase in mitosis, meiosis I, and meiosis II.
2. Create a graphic organizer to compare oogenesis and spermatogenesis.
3. Sea star cells have 36 chromosomes. If anaphase I does not occur, how many chromosomes will be present in daughter cells produced by meiosis?

Formation of Reproductive Cells

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Add meiosis-related terminology to the classroom word wall.
- Present videos and/or animations, sourced online, of cells undergoing meiosis.
- Present physical models (e.g., coloured beads that snap together, coloured paper clips) to simulate the behaviour of chromosomes during meiosis.
- Facilitate a game of *Who am I?* asking questions to identify the phase of mitosis or meiosis.
- Provide prepared slides of cells undergoing meiosis (e.g., lily anther, frog testis) for viewing using microscopes. Images sourced online may also be used.

Students may

- Add meiosis-related terminology to their visual dictionary.
- Use physical models to simulate the behaviour of chromosomes during meiosis.

Consolidation

Teachers may

- Assess knowledge and skill SCOs as part of a lab station test.

Students may

- Design and create a foldable to communicate the processes involved in the formation of reproductive cells.
- Create a flip book of the phases of meiosis I and II.
- Create a physical model of a cell undergoing meiosis.

Extension

Student may

- Investigate polyploidy in plants and animals.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 4 pp. 9-13

NL Biology (SR)

- pp. 463-472

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Meiosis resources
- Science supply companies

Reproductive Strategies

Outcomes

Students will be expected to

32.0 analyze and explain reproductive strategies among living organisms [GCO 3]

33.0 analyze natural systems to interpret and explain their structure and dynamics [GCO 1]

Focus for Learning

Asexual and sexual reproduction were introduced in Science 9. In Biology 3201, students should

- distinguish between asexual and sexual reproduction;
- explain the human life cycle (i.e., meiosis, haploid gametes, fertilization, diploid zygote, mitosis);
- describe asexual reproductive strategies (i.e., binary fission, budding, vegetative reproduction, fragmentation, parthenogenesis, spores) and identify example organisms;
- describe the reproductive strategy of viruses (i.e., lytic, lysogenic);
- explain alternation of generations and analyze life cycles of moss and a representative cnidarian to identify the haploid and diploid generations;
- identify and describe the function of reproductive structures in flowering plants (i.e., stamen, anther, filament, pollen, pistil, stigma, style, ovary, ovules);
- analyze the life cycle of a flowering plant and explain its structure and dynamics (i.e., sporophyte, gametophytes, ovule, megaspores, polar nuclei, microspores, pollen grain, generative nucleus, tube nucleus, embryo, 3n (triploid) endosperm, double fertilization, haploid, diploid, seed, fruit); and
- compare advantages and disadvantages of asexual and sexual reproduction.

9.0 select and use apparatus and materials safely [GCO 2]

26.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise [GCO 2]

Students are expected to dissect a flower (e.g., alstroemeria, daffodil, lily, tulip) to view and identify male and female reproductive structures. Dissection should include a cross section of the ovary.

Students' effective use of hand lenses, safe use of dissection tools (SCO 9.0), and ability to work cooperatively (SCO 26.0) should be assessed. SCO 13.0 may also be assessed if students are required to create a labelled biological drawing of their dissected flower. Refer to the *Integrated Skills* unit for elaboration of these skills.

Note, for individual students with allergies, virtual or video dissection should be used as an alternative.

Attitude

Encourage students to show concern for safety and accept the need for rules and regulations. [GCO 4]

Sample Performance Indicators

1. Identify the reproductive structures of a flower.
2. A herbicide prevents the formation of the tube nucleus. How might this affect reproduction of the plant?
3. Identify the reproductive strategy and haploid and diploid stages in representative life cycles.

Reproductive Strategies

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present images of diverse organisms and ask students to predict how they might reproduce.
- Assess students' prior knowledge of asexual and sexual reproduction.

Connection

Teachers may

- Add terminology related to reproductive strategies to the classroom word wall.
- Present videos, sourced online, depicting reproductive strategies, including viral reproduction.
- Present life cycles of representative organisms for analysis.

Students may

- Add terminology related to reproductive strategies to their visual dictionary.
- Create summary cards of different asexual reproductive strategies.
- In small collaborative groups, create a digital presentation to depict the diversity of reproductive strategies among living things.
- Use personal mobile devices to capture images as a record of the flower dissection activity. Images can be inserted into digital lab reports and annotated to identify reproductive structures.

Consolidation

Teachers may

- Facilitate Activity 12.2 (*NL Biology*, p. 478), asking students to research and analyze different reproductive strategies and communicate their advantages and disadvantages.
- Assess knowledge and skill SCOs as part of a lab station test.

Students may

- Create a foldable to compare different reproductive strategies.
- Explain the importance of the triploid endosperm in the life cycle of a flowering plant.

Extension

Students may

- Explore the reproduction strategies of other organisms.
- Explore indigenous or medicinal uses of plants.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 4 pp. 13-21

NL Biology (ST)

- pp. 473-483

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Reproductive strategies resources
- Life cycles resources
- Science supply companies

Human Reproductive Systems

Outcomes

Students will be expected to

34.0 analyze and describe the structure and function of human male and female reproductive systems [GCO 3]

33.0 analyze natural systems to interpret and explain their structure and dynamics [GCO 1]

7.0 use library and electronic research tools to collect information on a given topic [GCO 2]

17.0 identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information [GCO 2]

Focus for Learning

The human reproductive system was introduced in Science 9.

Students should

- identify human male reproductive structures and describe their functions (i.e., testes [gonads], scrotum, seminiferous tubules, interstitial cells, epididymis, vas (ductus) deferens, penis, seminal vesicle, prostate gland, Cowper's gland, urethra);
- describe the path sperm travels through the human male reproductive system;
- identify human female reproductive structures and describe their functions (i.e., ovaries [gonads], follicle, fimbriae, oviducts (fallopian tubes), uterus, endometrium, cervix, vagina); and
- describe the path an egg travels through the human female reproductive system.

In small collaborative groups, students should select and research a common sexually transmitted infection (STI) (e.g., chlamydia, gonorrhea, hepatitis, herpes, human immunodeficiency virus [HIV], human papillomavirus [HPV], syphilis) using information sources they've evaluated and deemed credible and reliable. Their research should identify whether the selected STI is viral or bacterial, risks for transmission, symptoms, prevention information, testing, treatment, and reproductive complications if left untreated. Findings should be shared with peers.

This research investigation provides an opportunity to assess SCOs 7.0 and 17.0. In addition, teachers may assess SCOs 8.0, 26.0, and 27.0. Refer to the *Integrated Skills* unit for elaboration of these skills.

Note, for assessment purposes, students should be expected to

- identify examples of bacterial STIs and viral STIs,
- differentiate treatment for bacterial STIs from viral STIs, and
- describe complications (effects) for male and female reproductive systems if STIs are left untreated.

Attitude

Encourage students to acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research. [GCO 4]

Sample Performance Indicators

1. If an individual's seminal vesicle does not function properly, how will this affect his semen and sperm?
2. Annotate an unlabelled diagram of human female reproductive system to identify structures and their primary function.
3. Develop an education tool, aimed at teenagers, to effectively communicate key information and messages gleaned from their research on the risks and dangers of a STI.

Human Reproductive Systems

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Add reproductive system-related terminology to the classroom word wall.
- Present videos and/or animations, sourced online, depicting the structure and function of the human male and female reproductive systems.
- Facilitate Investigation 13.A (*NL Biology*, p. 491) to view and compare prepared slides of testicular and ovarian tissue or view electron micrographs, sourced online.
- Discuss possible sources of information on STIs and the importance of evaluating sources for credibility and reliability.
- Invite a public health official to lead an information session about STIs and their effects on male and female reproductive systems.

Students may

- Add new terminology to their visual dictionary.
- Design an infographic, pamphlet, advertisement, or other creative product to educate peers on common STIs and their prevention.

Consolidation

Teachers may

- Use a cooperative jigsaw activity to facilitate the STI research investigation.
- Facilitate an activity simulating the transmission of a STI. Procedures, using sodium hydroxide and phenolphthalein indicator, can be sourced online.

Students may

- Using unlabelled diagrams of the human male and female reproductive systems, orally describe the path sperm and egg travel, identifying reproductive structures and their functions.
- Infer why human males produce microscopic sperm in high quantities while females produce single, large eggs.
- Communicate the findings of their STI research group in a shared class digital document or presentation.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 4 pp. 22-27

NL Biology (ST)

- pp. 486-494

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Human reproductive system resources
- STI resources

Regulation of the Human Reproductive System

Outcomes

Students will be expected to

35.0 explain the human reproductive cycle [GCO 3]

33.0 analyze natural systems to interpret and explain their structure and dynamics [GCO 1]

13.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots [GCO 2]

14.0 identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit [GCO 2]

15.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables [GCO 2]

Focus for Learning

Concepts required to understand the role of the endocrine system (e.g., glands, hormones, feedback mechanisms) in regulating the human reproductive system were addressed in Biology 2201.

Students should

- identify reproductive hormones and describe their function in male and female reproductive systems (i.e., gonadotropin releasing hormone [GnRH], follicle-stimulating hormone [FSH], luteinizing hormone [LH], testosterone, inhibin, estrogen, progesterone);
- explain how hormone feedback mechanisms regulate the male reproductive system and the female menstrual cycle; and
- explain the ovarian (include follicular, ovulation, luteal, and menstruation stages) and uterine cycles.

Students are expected to analyze blood hormone data to infer associated physiological events in reproductive systems, including

- the onset of puberty and andropause or menopause, and
- ovarian and uterine events during the female menstrual cycle.

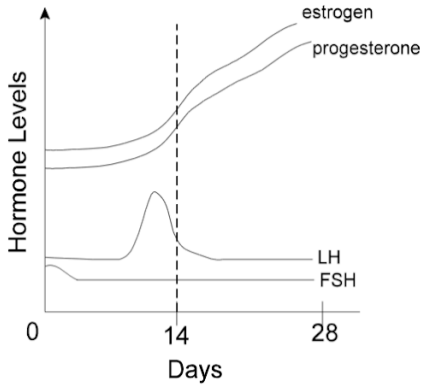
As part of these activities, students should

- construct graphs from data (SCO 13.0),
- identify the line or curve of best fit and interpolate or extrapolate based on the line (SCO 14.0), and
- analyze graphs and tables and interpret patterns and trends in data and make inferences (SCO 15.0).

Refer to the *Integrated Skills* unit for elaboration of these skills. Activity 13.2 and Investigation 13.B (*NL Biology*, pp. 497 and 502) may help to address these expectations.

Sample Performance Indicators

1. Infer two possible explanations for the hormonal levels below.



2. Explain how testosterone levels may change if LH levels drop.

Regulation of the Human Reproductive System

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Diagram how negative and positive feed back mechanisms work.

Connection

Teachers may

- Discuss steroid use and their potential side effects.
- Facilitate a discussion regarding the impact of aging on male and female reproductive systems.
- Present unlabelled diagrams of regulation of male and female reproductive systems. Ask students to annotate them identifying structures and hormones.

Students may

- Create a cartoon to illustrate how negative feedback loops maintain homeostasis.
- Summarize information about the regulation of the male and female reproductive hormone cycles in a flow chart, table, or similar format.
- Research and discuss the effects of endocrine-disrupting chemicals (e.g., DDT, BPA, phthalates, PCB, hormones used in livestock) on male and female reproductive health.

Consolidation

Students may

- Visually represent the negative feedback loops that regulate the male and female reproductive systems.
- Create a foldable to explain the stages of the menstrual cycle.
- Visually represent the ovarian and uterine cycles.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 4 pp. 27-31

NL Biology (ST)

- pp. 495-502
- pp. 218-220
- pp. 376-382

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Blood hormone analysis resources

Human Development - Fertilization to Birth

Outcomes	Focus for Learning
Students will be expected to	
36.0 describe the process of human development from fertilization to birth [GCO 3]	Students should • identify and describe the stages, processes, structures, and key events occurring during embryonic development, including - fertilization, zygote; - cleavage, morula, blastocyst, trophoblast, implantation, secretion of human chorionic gonadotropin (hCG); - gastrulation, primary germ layers (i.e., ectoderm, mesoderm, endoderm), gastrula, morphogenesis, differentiation, neurulation, neurula, organ formation, embryo; and - extra-embryonic membranes (i.e., chorion, amnion, allantois, yolk sac), placenta, umbilical cord; • identify stages (i.e., trimesters) and key events (i.e., sex differentiation, heart beat detection, viability) in fetal growth and refinement; • describe the formation of fraternal and identical twins; • describe the parturition process (i.e., dilation, expulsion, placental stages); • explain the positive feedback mechanisms controlling parturition and lactation; and • describe the effects of teratogens (e.g., cigarette smoke, alcohol, prescription and over the counter medications, infectious disease, radiation, chemical pollutants) on embryonic and fetal development.
37.0 identify examples where technologies were developed based on scientific understanding [GCO 1] 24.0 identify multiple perspectives that influence a science-related decision or issue [GCO 2]	Students are further expected to • describe prenatal screening technologies (i.e., home pregnancy tests, maternal blood tests, ultrasound, amniocentesis, chorionic villi sampling, cell-free DNA prenatal screening, fetoscopy), the information they provide, and the scientific understandings upon which they are based; and • analyze issues and decisions arising from prenatal screening. **Attitude** Encourage students to show a continuing and more informed curiosity and interest in science and science-related issues. [GCO 4] **Sample Performance Indicators** 1. Using unlabelled diagrams of the embryonic and fetal development periods, orally describe the processes and key events along the development pathway. 2. What might happen to the development of an embryo if a teratogen effected the chorion layer of the trophoblast? 3. Infer why chick embryos might have a significant amount of yolk but human embryos do not.

Human Development - Fertilization to Birth

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present ultrasound images from various stages of pregnancy.
- Provide a series of images of developing embryos and ask students to arrange them chronologically.

Connection

Teachers may

- Present videos, sourced online, depicting human development.
- Discuss differences between embryonic and fetal development periods.

Students may

- Add human development-related terminology to their visual dictionary.
- Graph human embryo size (length) during the first 56 days (*NL Biology*, p. 485) to visualize embryonic development.
- Create a graphic organizer (e.g., flow chart) to describe embryonic development from ovulation to implantation.
- Engage in Investigation 13.C (*NL Biology*, p. 517) to observe embryonic development and compare human and chick embryos.
- Visually represent the hormonal regulation of parturition using a graphic organizer.
- Use a cooperative jigsaw strategy to research prenatal screening technologies and share findings with other group members.

Consolidation

Students may

- Create a digital presentation to show development through the embryonic and fetal periods.
- Examine diagrams to compare human embryonic development to that of other animals.
- Research known teratogens (e.g., thalidomide) and their effect on human development.
- Research forms of non-invasive prenatal testing.
- Research best practices to ensure healthy pregnancies.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 4 pp. 22-23, 33-38

NL Biology (ST)

- pp. 484-485,
- pp. 508-526

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Human development resources

Reproductive Technologies

Outcomes

Students will be expected to

38.0 evaluate and describe reproductive technologies [GCO 3]

37.0 identify examples where technologies were developed based on scientific understanding [GCO 1]

39.0 construct arguments to support a decision or judgement, using examples and evidence and recognizing various perspectives [GCO 1]

40.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology [GCO 1]

41.0 debate the merits of funding specific scientific or technological endeavours and not others [GCO 1]

Focus for Learning

Students should

- identify causes of infertility and sterility in males and females;
- describe reproductive technologies to enhance the ability to conceive, including, but not limited to, artificial insemination [AI], in vitro fertilization [IVF], surrogacy, superovulation, and cryopreservation; and
- describe reproductive technologies to prevent conception, including, but not limited to, natural methods, physical or chemical barriers, hormonal contraception, and surgical sterilization.

In small collaborative groups, students are expected to research and evaluate conception prevention technologies using credible and reliable sources of information. They should consider factors such as the safety and effectiveness of specific reproductive technologies, identify advantages and disadvantages, and recommend the best course of action for particular situations.

As part of this research activity, teachers may assess SCOs 7.0, 8.0, 17.0, 24.0, 25.0, 26.0, and 27.0. Refer to the *Integrated Skills* unit for elaboration of these skill outcomes.

Reproductive technologies provide a context to examine the relationships among science, technology, and society. Specifically, students should

- discuss the risks and benefits to society of reproductive technology use,
- debate ethical and moral questions that arise from reproductive technology use, and
- debate the merits of funding research to enhance conception versus controlling human population growth.

Attitudes

Encourage students to

- be aware of the direct and indirect consequences of their actions, and
- appreciate that applications of science and technology can raise ethical dilemmas. [GCO 4]

Sample Performance Indicator

Construct arguments to support an assigned position (i.e., for or against) with respect to a question below. Defend your assigned position in a debate.

- Should provincial health plans cover fertility treatments?
- Should contraception be universally provided at no cost?

Reproductive Technologies

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Facilitate a cooperative jigsaw activity for students to research reproductive technologies that enhance the ability to conceive.
- Create situational cards. Read the situation and ask students to identify the most appropriate reproductive technology for the situation.

Consolidation

Students may

- Debate which conception-enhancing and which conception-preventing technologies are most safe and effective.
- Carry out a risk/benefit analysis of selected reproductive technologies.

Extension

Students may

- Research reproductive technologies used in large scale plant and animal breeding.

Resources and Notes

Authorized

NL Biology (ST)

- pp. 503-507

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Reproductive technologies resources

Stem Cells

Outcomes	Focus for Learning
Students will be expected to	
42.0 analyze society's influence on scientific and technological endeavours [GCO 1]	Stem cells provide a context to examine society's influence on scientific and technological endeavours. Students should • describe the unique properties of stem cells; • distinguish between and identify sources of embryonic and adult stem cells, include pluripotent and multipotent; • research and discuss applications of stem cell research, including drug testing and therapeutic uses; • discuss ethical questions arising from embryonic stem cell research; and • analyze society's influence on stem cell research (e.g., limiting government funding for embryonic stem cell research).
43.0 identify and describe science- and technology-based careers related to the science they are studying [GCO 1]	While SCO 43.0 is positioned at the end of this unit, science- and technology-related careers may be addressed at any point deemed appropriate. Students should identify and describe careers related to reproductive science. Note, *NL Biology* includes a feature focus on careers related to childbirth and conception (pp. 530-531).
	Attitude Encourage students to consider further studies and careers in science- and technology-related fields. [GCO 4]

Stem Cells

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Present videos, sourced online, describing stem cells, their sources, and uses.

Students may

- Debate the ethics of embryonic/cord blood stem cell research and use.

Consolidation

Students may

- Engage in a cooperative jigsaw activity to research stem cell technology and current applications.

Extension

Students may

- Explore induced pluripotent stem cells.

Resources and Notes

Authorized

NL Biology (ST)

- p. 524
- p. 365
- pp. 530-531

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Stem cell resources

Section Three:
Specific Curriculum Outcomes

Unit 2: Genetic Basis of Heredity

Focus

Much of the structure and function of living organisms is determined by genetic material. It is important for a scientifically literate person to understand principles and fundamentals about genetic material and why this major area of scientific and technological endeavour has implications for humans and planet Earth.

The unit emphasizes the social and environmental contexts of science and technology and the unifying concept of constancy and change.

Outcomes Framework

GCO 1 (STSE): Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

39.0 construct arguments to support a decision or judgement, using examples and evidence and recognizing various perspectives
40.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology
43.0 identify and describe science- and technology-based careers related to the science they are studying
44.0 illustrate how science attempts to explain natural phenomena
45.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge
48.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced
51.0 compare processes used in science with those used in technology
52.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology
54.0 explain how a major scientific milestone revolutionized thinking in the scientific communities

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

46.0 summarize the events and experiments that led to the concept of the gene
47.0 demonstrate an understanding of Mendelian genetics and predict the outcome of various genetic crosses
49.0 describe the role of chromosomes in the transmission of hereditary information from one cell to another
50.0 explain circumstances that lead to genetic disorders
53.0 compare and contrast the structures of DNA and RNA
55.0 explain the replication of DNA
56.0 explain the roles of DNA and RNA in protein synthesis
57.0 predict the effects of mutations on protein synthesis, phenotypes, and heredity
58.0 describe factors that may lead to mutations in a cell's genetic information
59.0 demonstrate an understanding of current genetic technologies

GCO 2 (Skills): Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

2.0 state a prediction and a hypothesis based on available evidence and background information
6.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data
9.0 select and use apparatus and materials safely
10.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials
15.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
20.0 construct and test a prototype of a device or system and troubleshoot problems as they arise
21.0 evaluate a personally designed and constructed device on the basis of criteria they have developed themselves
25.0 develop, present, and defend a position or course of action, based on findings
27.0 evaluate individual and group processes used in planning, problem solving and decision making, and completing a task

GCO 4 (Attitudes): Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Students are encouraged to

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- appreciate that the applications of science and technology can raise ethical dilemmas
- value the contributions to scientific and technological development made by individuals from many societies and cultural backgrounds
- show a continuing and more informed curiosity and interest in science and science-related issues
- consider further studies and careers in science- and technology-related fields
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas
- project the personal, social, and environmental consequences of proposed action
- show concern for safety and accept the need for rules and regulations

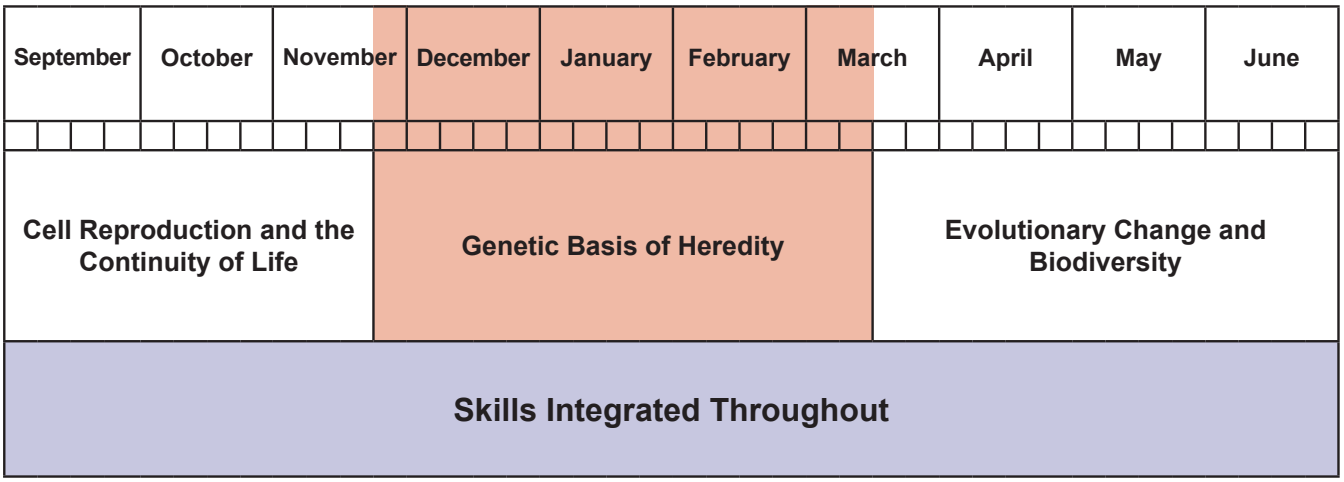
SCO Continuum

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

Science 9	Biology 2201	Biology 3201
Reproduction	*Maintaining Homeostasis*	*Genetic Basis of Heredity*
• illustrate and describe the basic process of cell division, including what happens to the cell membrane and the contents of the nucleus. • explain signs of pregnancy and describe the major stages of human development from conception to early infancy • recognize that the cell nucleus contains genetic information and determines cellular processes. • distinguish between sexual and asexual reproduction in representative organisms. • compare sexual and asexual reproduction in terms of their advantages and disadvantages • compare the structure and function of the human reproductive systems • discuss factors that may lead to changes in a cell's genetic information	• explain how systems help maintain homeostasis • analyze homeostatic phenomena to identify the feedback mechanisms involved • explain how tropisms help to maintain homeostasis • analyze the impact of factors on the homeostasis of the nervous system • evaluate the impact of disorders and diseases on homeostasis • explain the importance of fitness to the maintenance of homeostasis • describe the impact of environmental factors on homeostasis • explain the role of enzymes in metabolism • explain the importance of nutrition to the maintenance of homeostasis	• summarize the events and experiments that led to the concept of the gene • demonstrate an understanding of Mendelian genetics and predict the outcome of various genetic crosses • describe the role of chromosomes in the transmission of hereditary information from one cell to another • explain circumstances that lead to genetic disorders • compare and contrast the structures of DNA and RNA • explain the replication of DNA • explain the roles of DNA and RNA in protein synthesis • predict the effects of mutations on protein synthesis, phenotypes, and heredity • describe factors that may lead to mutations in a cell's genetic information • demonstrate an understanding of current genetic technologies

Suggested Unit Plan

The *Genetic Basis of Heredity* unit precedes the *Evolutionary Change and Biodiversity* unit. Knowledge outcomes addressed in this unit are prerequisite to understanding evolutionary concepts.



Mendelian Genetics - Patterns and Processes of Inheritance

Outcomes

Students will be expected to

44.0 illustrate how science attempts to explain natural phenomena [GCO 1]

45.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge [GCO 1]

46.0 summarize the events and experiments that led to the concept of the gene [GCO 3]

47.0 demonstrate an understanding of Mendelian genetics and predict the outcome of various genetic crosses [GCO 3]

2.0 state a prediction and a hypothesis based on available evidence and background information [GCO 2]

6.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data [GCO 2]

15.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables [GCO 2]

Focus for Learning

The study of genetics provides a context to explore how science attempts to explain natural phenomena and how scientific knowledge develops through evidence, theories, and paradigms.

Students should

- examine early historical explanations of the mechanism of inheritance and summarize the experiments that led to Mendel's theory of inheritance;
- explain and use the following inheritance-related terminology
  - genetics, trait, dominant, recessive, gene, allele;
  - genotype, phenotype, homozygous, heterozygous (avoid use of the term hybrid to describe heterozygous genotypes);
  - Punnett square, P, F_1, and F_2 generations, test cross; and
  - complete dominance, incomplete dominance, co-dominance;
- explain the laws of segregation and independent assortment;
- compare ratios of genotypes and phenotypes for crosses with dominant and recessive alleles, incompletely dominant alleles, and co-dominant alleles; and
- interpret inheritance patterns and predict the outcomes of one and two trait crosses (include monohybrid and dihybrid) and crosses involving incomplete dominance and co-dominance.

Students should be familiar with various forms of allele notation (e.g., *Rr*, R_1R_2, *RR'*, *RW*, I^AI^B).

Student use of Punnett squares to analyze crosses provides opportunities to assess skill outcomes related to predicting results (SCO 2.0), organizing data (SCO 6.0), and interpreting patterns and trends (SCO 15.0). Refer to the *Integrated Skills* unit for elaboration.

Attitudes

Encourage students to value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not. [GCO 4]

Sample Performance Indicators

1. In corn plants, the alleles for thick husks (*T*) and green seeds (*G*) are completely dominant to thin husks (*t*) and yellow seeds (*g*). Two thick husked, green seed plants are crossed and one of the plants produced has a thin husk and yellow seeds. What percentage of the offspring share the same genotype as the parents? What is the phenotypic ratio of the plants produced? Show all workings.
2. Roan colouration in horses is a trait that shows co-dominance. Two blue roan horses are bred together. What are the genotype and phenotype ratios of their offspring?

Mendelian Genetics - Patterns and Processes of Inheritance

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Survey students for presence of genetic traits (e.g., attached versus free-hanging ear lobes, peaked versus smooth hairline, tongue rolling, hair colour).
- Present images of famous individuals and their biological parents. Ask students to identify traits that they may have inherited from each parent.
- Facilitate the coin toss launch lab (*NL Biology*, p. 541) to review probability and how it is used in the study of genetics.

Connection

Teachers may

- Require students to create a personal portfolio to house solutions to assigned genetics problems.
- Create a class word wall of unit terminology.
- Present videos, sourced online, depicting Mendel's experiments.

Students may

- Explore probability using coins annotated with a dominant allele on one side and a recessive allele on the other. Tossing both coins represents possible allele combinations.
- Create a personal, visual dictionary of unit-related terminology and refer to the terminology when communicating.

Consolidation

Students may

- Answer questions and solve problems such as
  - In Mendel's first experiment, he obtained 752 inflated pod and 256 pinch pod pea plants. Which concept or law does this evidence support? Justify your answer.
  - Two parents are crossed and 75% of the offspring have no freckles while 25% have freckles. What are the genotypes and phenotypes of the parents?
  - In certain species of fish, blue scales and yellow scales are incompletely dominant. Predict the outcome between two heterozygous fish.
  - How would you determine whether a fruit fly is homozygous or heterozygous for long wings?

Extension

Students may

- Use Punnett squares to analyze three trait crosses.

Resources and Notes

Authorized

NL Biology
(Teacher Resource [TR])

- Unit 5 pp. 1-12

NL Biology
(Student Resource [SR])

- pp. 536-553

Teaching and Leaning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/teaching-and-learning-strategies.html
  - Interactive Games

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Mendelian genetics resources
- Punnett square resources

Extending Mendel's Laws

Outcomes

Students will be expected to

48.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced
[GCO 1]

49.0 describe the role of chromosomes in the transmission of hereditary information from one cell to another
[GCO 3]

47.0 demonstrate an understanding of Mendelian genetics and predict the outcome of various genetic crosses
[GCO 3]

Focus for Learning

The development and evolution of the chromosome theory of inheritance and the extension of Mendel's laws to account for other inheritance patterns (e.g., polygenic, multiple alleles) provides a context to explore how scientific knowledge evolves. The importance of communicating scientific findings and peer review may also be explored.

Students should

- explain the Sutton-Boveri chromosome theory of inheritance and Morgan's amendment, the gene-chromosome theory;
- explain inheritance patterns for genes on the same chromosome;
- describe how gene linkage and crossing over impact variation;
- describe and interpret sex-linked inheritance patterns and predict the outcome of crosses involving sex-linked traits;
- describe and interpret inheritance patterns for traits controlled by multiple alleles, including, but not limited to, ABO blood types (include Rh factors), and predict the outcome of crosses;
- describe and interpret polygenic inheritance patterns and predict the outcome of crosses;
- describe examples of environmental conditions affecting gene expression; and
- recognize sex-linked, multiple allele, and polygenic inheritance patterns as extensions of Mendel's laws.

Attitudes

Encourage students to show a continuing and more informed curiosity and interest in science and science-related issues. [GCO 4]

Sample Performance Indicators

1. Eye colour in fruit flies is a sex-linked trait. A homozygous red-eyed female is crossed with a white-eyed male. Two offspring from the F_1 generation are then crossed. Predict the genotype and phenotype ratios of the F_2 generation of fruit flies.
2. Colour vision deficiency is a sex-linked recessive trait. A male with type I^AI^B blood, who has normal vision reproduces with a woman who has type I^Ai blood and is a carrier of the colour vision deficient allele. What is the probability that they will have a colour vision deficient child with type B blood? Support your answer with a Punnett square.
3. The police have rounded up the usual suspects in the latest rash of bookstore robberies. The thief got a nasty paper cut at the scene of the crime. The suspects are of O, A, B, and AB blood types. The blood at the crime scene contains *i* alleles. Which suspect could not have been involved? Explain.

Extending Mendel's Laws

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Present data from Morgan's experiments and ask students to find a pattern of inheritance.
- Present videos or animations, sourced online, explaining gene linkage.
- Discuss analogies to explain gene linkage (e.g., If ten students are in a line and you throw a bucket of water at one, those nearest to the student are most likely to get wet).
- Present examples where environmental factors impact gene expression (e.g., temperature [Siamese cats, curly wings fruit flies, seasonal change in hares, sex determination in reptiles], sunlight [human skin, hair colour], pH [hydrangea colour], diet/nutrient availability).

Students may

- Add new terminology to their visual dictionary.
- Add solved genetics problems to their personal portfolio.
- Explain why sex-linked, recessive disorders are more prevalent in males.

Consolidation

Students may

- Practice analyzing crosses involving sex-linked and multiple alleles such as
  - The table below shows the gene pairs involved in determining eye color. If a man with grey-blue eyes is crossed with a woman with green eyes, use a Punnett square to determine the genotype and phenotype ratios of their offspring.

Genotype	Eye Colour
AA BB	black-brown
AA Bb	dark brown
AA bb	brown
Aa BB	brown-green flecked
Aa Bb	light brown
Aa bb	grey-blue
aa BB	green
aa Bb	dark blue
aa bb	light blue

Resources and Notes

Authorized

NL Biology (TR)

- Unit 5 pp. 12-19

NL Biology (SR)

- pp. 553-563

Teaching and Leaning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/teaching-and-learning-strategies.html
  - Interactive Games

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Sex-linked, multiple allele, and polygenic inheritance resources

Human Genetics

Outcomes

Students will be expected to

50.0 explain circumstances that lead to genetic disorders [GCO 3]

47.0 demonstrate an understanding of Mendelian genetics and predict the outcome of various genetic crosses [GCO 3]

2.0 state a prediction and a hypothesis based on available evidence and background information [GCO 2]

15.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables [GCO 2]

Focus for Learning

Genetic disorders, including those caused by chromosomal changes, are addressed later in the unit (p. 98). At this point, students should

- recognize pedigrees as an important tool for studying inherited genetic disorders;
- interpret pedigrees that show inheritance of autosomal dominant, autosomal recessive, sex-linked, and multiple allele traits; and
- analyze pedigrees to identify unknown genotypes and phenotypes (e.g., Activity 14.5, *NL Biology*, p. 567).

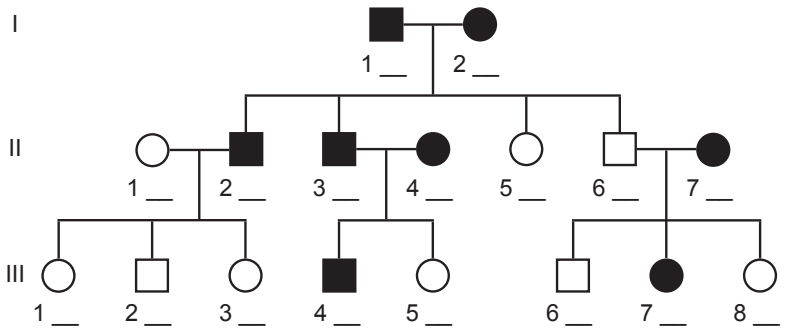
Students should be familiar with symbols used in pedigrees (*NL Biology*, p. 564). For the purpose of assessment, the symbols for known heterozygotes and known carriers of X-linked recessive traits should be excluded from pedigrees.

Student use of pedigrees to analyze inheritance of a trait, provides additional opportunities to assess skill outcomes related to predicting and interpreting patterns (i.e., predicting phenotypes and genotypes and interpreting patterns of inheritance). Refer to the *Integrated Skills* unit for elaboration.

Sample Performance Indicator

Examine the pedigree below.

- Does it show a sex-linked inheritance pattern? Explain.
- How it is possible that individual III 5 is unaffected? Explain.



Human Genetics

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present the pedigree for inheritance of hemophilia in European royal families and ask students to interpret the diagram.

Connection

Teachers may

- Present pedigrees, sourced online, for single trait, sex-linked, and multiple allele inheritance patterns. Ask students to analyze and interpret them.
- Invite a genetic counsellor to present to the class about the use of pedigree charts in studying inherited disorders.

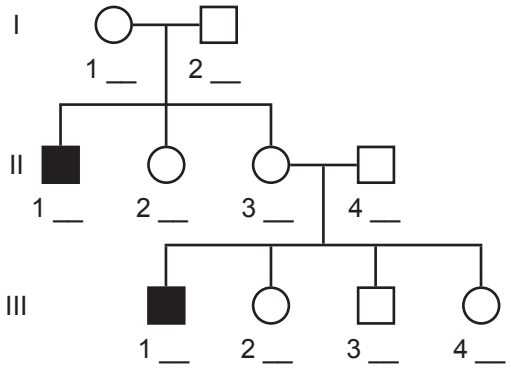
Students may

- Add solved pedigree problems to their personal portfolio.
- Create a pedigree from provided information to represent inheritance of a trait or disorder within a family.

Consolidation

Students may

- Create a pedigree analysis “how to” guide to help identify the different types of inheritance patterns.
- Choose a trait or genetic disorder and create a pedigree chart consistent with the inheritance pattern. Share your pedigree with peers and ask them to identify the type of inheritance pattern.
- Practice analyzing and interpreting pedigrees.
  - What can you deduce about the pattern of inheritance for the pedigree below? Identify possible genotypes and phenotypes for individuals I 2 and III 4.



Resources and Notes

Authorized

NL Biology (TR)

- Unit 5 pp. 9-24

NL Biology (SR)

- pp. 564-568

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Pedigree resources

Notes

Pedigree charts obtained from different sources may use different symbols.

Molecular Genetics

Outcomes

Students will be expected to

9.0 select and use apparatus and materials safely [GCO 2]

10.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials [GCO 2]

51.0 compare processes used in science with those used in technology [GCO 1]

Focus for Learning

To transition to molecular genetics, students are expected to engage in a DNA extraction investigation. They should follow a provided procedure (e.g., *NL Biology,* p. 581) to extract DNA from plant tissues (e.g., banana, strawberry).

Note, be aware of food allergies and modify materials accordingly.

As part of this investigation, assess students' safe use of glassware and personal protective equipment (SCO 9.0) and their technique for handling and disposing of chemicals (e.g., NaCl solution, isopropanol) and plant tissues (SCO 10.0). Additionally, teachers may assess SCO 19.0 (i.e., identify and correct practical problems in the way a process functions) and SCO 26.0 (i.e., work cooperatively with team members to carry out a plan and troubleshoot problems as they arise) at this time. Refer to the *Integrated Skills* unit for elaboration of these outcomes.

The procedure to extract DNA should be used as a context to compare processes used in science with design processes used in technology (i.e., engineering). Students should analyze procedural steps and brainstorm potential modifications in the design that might improve efficiency of the extraction process.

Attitudes

Encourage students to show concern for safety and accept the need for rules and regulations. [GCO 4]

Molecular Genetics

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Review WHMIS standards for handling and disposing of lab materials.

Connection

Teachers may

- Present a physical model of DNA and provide an overview of its molecular basis.
- Present the Mr. DNA sequence from the film *Jurassic Park*.
- Ask students to share things they have recently read about applications of DNA and then evaluate the reliability of claims.
- Discuss why we might want to extract DNA from an organism.
- Present videos, sourced online, depicting how human DNA is extracted.

Students may

- View extracted DNA using a stereoscope.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 5 pp. 31-32

NL Biology (SR)

- p. 581

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- DNA extraction resources
- Science supply companies

Notes

The magnifying glass icon is used throughout the unit to indicate investigations.

DNA Structure

Outcomes

Students will be expected to

48.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced [GCO 1]

52.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology [GCO 1]

53.0 compare and contrast the structures of DNA and RNA [GCO 3]

54.0 explain how a major scientific milestone revolutionized thinking in the scientific communities [GCO 1]

Focus for Learning

Students should

- summarize the events, experiments, and evidence that led to the discovery of the structure and function of DNA, including the contributions of the following individuals
  - Miescher;
  - Levene;
  - Griffith;
  - Avery, MacLeod, and McCarty;
  - Hershey and Chase;
  - Chargaff;
  - Franklin; and
  - Watson and Crick;
- recognize the use of radioactive labelling to show genes are made of DNA, as an example of how scientific understanding was enhanced as a result of the invention of a technology;
- describe the double helix structure of DNA, including nucleotides, complementary base pairs, and antiparallel (3’ 5’ ends) strands;
- describe structural and functional differences between DNA and RNA; and
- explain the relationships among genes, DNA, proteins, chromosomes, and the genome.

Students should recognize that the discovery of the double helix marked a milestone in the history of science. The discovery yielded ground-breaking insights into the genetic code and protein synthesis and helped to produce new and powerful genetic engineering techniques.

Attitude

Encourage students to value the contributions to scientific and technological development made by individuals from many societies and cultural backgrounds. [GCO 4]

Sample Performance Indicators

1. Describe one of the experiments that contributed to the study of DNA. How were the results of this experiment used by other researchers in subsequent work?
2. Does the coding sequence below represent DNA or RNA? Explain.

   GCU - ACG - GAG - CUU - CGG - AGC - UAG

3. Create an annotated sketch to represent the structure of DNA.

DNA Structure

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Facilitate a “headbands” type game to review the scientists involved in the discovery of the structure and function of DNA.

Connection

Teachers may

- Present videos, sourced online, recounting the discovery of the structure and function of DNA.
- Use Rosalind Franklin and Linus Pauling as examples to discuss how society influences science (FYI feature, *NL Biology*, p. 588).
- Discuss how the discovery of DNA required individuals from multiple scientific disciplines and interdisciplinary studies (e.g., physicians and medical officers, geneticists, physicists, biochemists).

Students may

- Add DNA-related terminology to their visual dictionary.
- Create a historical timeline for the discovery of the structure and function of DNA.
- Create a video, role playing a historical figure, to depict a significant event or experiment related to the discovery of the structure and function of DNA.

Consolidation

Students may

- Engage in Activity 15.1 DNA Deductions (*NL Biology*, p. 587).
- Debate which event, experiment, or evidence was most important to the discovery of the structure and function of DNA.

Extension

Students may

- Research similarities and differences between computer coding and genetic coding.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 2 pp. 11-13
- Unit 5 pp. 32-34

NL Biology (SR)

- pp. 131-134
- pp. 582-588

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- DNA structure resources

DNA Replication

Outcomes	Focus for Learning
Students will be expected to	
55.0 explain the replication of DNA [GCO 3]	Students should • describe the process of creating an exact copy of a molecule of DNA, including - initiation, elongation, and termination events; - functions of key enzymes (i.e., helicase, primase, DNA polymerase, DNA ligase); - replication bubbles and forks; and - leading strands, lagging strands, and Okazaki fragments; and • construct the complementary strand of DNA from a parent strand, and vice versa.
20.0 construct and test a prototype of a device or system and troubleshoot problems as they arise [GCO 2]	Students are expected to engage in an engineering design activity to construct a working model of a short DNA strand (8-10 base pairs). The model should show the molecular structure of DNA and be able to simulate the process of DNA replication (Investigation 15.A, *NL Biology*, p. 592).
21.0 evaluate a personally designed and constructed device on the basis of criteria they have developed themselves [GCO 2] 27.0 evaluate individual and group processes used in planning, problem solving and decision making, and completing a task [GCO 2]	In small collaborative groups, students should • clarify the assigned task and develop evaluation criteria; • brainstorm ideas, researching if necessary, and consider the potential strengths and weaknesses of each alternative idea before selecting one as the basis of a plan; • create a detailed design plan that includes required materials and equipment; • construct and test a prototype of their model, recording any changes to the design plan; • refine and retest the model, evaluating it against the criteria; and • present their model and use it to simulate the process of DNA replication. In addition to SCOs 20.0, 21.0, and 27.0, teachers may assess skill outcomes 9.0 and 26.0. Refer to the *Integrated Skills* unit for elaboration of these outcomes.
51.0 compare processes used in science with those used in technology [GCO 1]	Engaging in this engineering design activity provides another opportunity to compare technological design processes with processes used in scientific inquiry.
	Attitude Encourage students to work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas. [GCO 4]
	Sample Performance Indicators 1. Explain how DNA replication would be affected if DNA polymerase did not function properly. 2. Explain how the 3’ 5’ orientation impacts DNA replication.

DNA Replication

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Explain the semi-conservative nature of DNA replication.
- Present images of early historical models of the structure of DNA (e.g., conservative, dispersive, semi-conservative).
- Present videos or simulations, sourced online, showing the replication of DNA.
- Discuss how some cancer treatments target key enzymes involved in DNA replication.

Students may

- Add DNA replication-related terminology to their visual dictionary.
- Solve problems such as
  - Construct the complementary DNA strand for the following DNA base pair sequence GTA - CGC - TAC - TAG - ACT.
- Add solved DNA replication problems to their personal portfolio.

Consolidation

Students may

- Use coloured paper clips to model DNA replication.
- Sketch and annotate a diagram to describe the events involved in DNA replication, including enzyme locations.
- Create a video demonstrating how their personally constructed model simulates the replication of DNA.

Extension

Students may

- Research how replication rates differ for different cells.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 5 pp. 34-37

NL Biology (SR)

- pp. 588-593

Teaching and Leaning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/teaching-and-learning-strategies.html
  - Pilot Teacher Conversations

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- DNA replication resources

Protein Synthesis and Gene Expression

Outcomes

Students will be expected to

56.0 explain the roles of DNA and RNA in protein synthesis [GCO 3]

Focus for Learning

Students should

- explain how genetic information is encoded in DNA molecules and expressed in living cells;
- describe the processes of transcription and translation, include codons, messenger RNA (mRNA), RNA polymerases, transfer RNA (tRNA), anticodons, and ribosomal RNA (rRNA);
- engage with large-scale, physical models and/or virtual simulations of protein synthesis; and
- use mRNA codon tables to determine a protein's amino acid sequence from a DNA sequence and vice versa.

Note, students should be familiar with different types of codon tables.

Sample Performance Indicators

1. Complete the following using a mRNA codon table.

DNA	GAT			
mRNA		UAU		
tRNA			CCU	
Amino Acid				Start

2. If a mRNA strand has 20% Uracil, what percentage of Guanine would be present in the parent strand of DNA?

Protein Synthesis and Gene Expression

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Present videos, sourced online, depicting the process of protein synthesis.
- Simulate the processes of transcription and translation using diagrams and physical models.

Students may

- Add protein synthesis-related terminology to their visual dictionary.

Consolidation

Students may

- Complete Activities 15.2 and 15.3 (*NL Biology*, pp. 597-98).
- Add solved protein synthesis problems to their personal portfolio.

Extension

Students may

- Discuss why cells don't translate proteins directly from DNA.
- Research how introns (non-coding) and exons (coding) relate to DNA transcription.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 5 pp. 34-42

NL Biology (SR)

- pp. 588-600

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Protein synthesis resources
- Science supply companies

Mutations

Outcomes

Students will be expected to

57.0 predict the effects of mutations on protein synthesis, phenotypes, and heredity
[GCO 3]

50.0 explain circumstances that lead to genetic disorders [GCO 3]

58.0 describe factors that may lead to mutations in a cell's genetic information
[GCO 3]

Focus for Learning

Students should

- differentiate between somatic cell and germ line mutations;
- describe types of point mutations (i.e., insertion, deletion, or substitution of one or more nucleotides) and predict their effects on protein synthesis, phenotypes, and heredity (Insertions and deletions cause frameshifts);
- describe silent, mis-sense, and nonsense mutations;
- analyze DNA strands to identify the type of point mutation and infer effects;
- describe chromosomal mutations (i.e., deletion, duplication, inversion, and translocation) and predict their effects on protein synthesis, phenotypes, and heredity;
- analyze karyotypes to identify examples of nondisjunction including, but not limited to, Down, Patau, Edward, Turner, Klinefelter and Jacobs syndromes;
- differentiate between spontaneous and induced mutations;
- identify examples of physical and chemical mutagens; and
- describe the concept of epigenetics.

Sample Performance Indicators

1. Identify the type of point mutation in the DNA and, using a codon table, predict whether it results in a silent, mis-sense, or non-sense mutation.

   Original DNA strand TAC - TGC - CTC - CCC - ATA - AGA - ATT

   Mutated DNA strand TAC - TGC - CTC - CCC - ATT - AGA - ATT

2. How is it possible that some, but not all, mutations get passed from one generation to the next?
3. Analyze a human karyotype and identify the type of nondisjunction disorder indicated.

Mutations

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Use the alphabet analogy, creating 3 letter words and combining them to make sentences (genes) and paragraphs (chromosomes). This analogy can be extended later to depict mutations.
- Facilitate a mutation-related virtual lab.

Connection

Teachers may

- Discuss the relative impact of somatic and germ cell mutations.

Students may

- Add mutation-related terminology to their visual dictionary.
- Engage in a karyotyping virtual simulation activity.
- Add solved mutation-related problems to their personal portfolio.

Consolidation

Students may

- Create a foldable to distinguish between types of mutations and their effects.
- Debate whether substitution, frameshift, or chromosome mutations would have a greater effect on a cell.

Extension

Students may

- Research a chromosomal disorder caused by deletion, duplication, inversion, or translocation.
- Research the heterozygous advantage of a sickle cell missense mutation.
- Research genetic disorders prevalent in Newfoundland and Labrador populations.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 5 pp. 23-27
- Unit 5 pp. 42-44

NL Biology (SR)

- pp. 601-605
- pp. 568-573

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Mutations/Genetic disorders resources

Genomics and Genetic Technologies

Outcomes

Students will be expected to

59.0 demonstrate an understanding of current genetic technologies [GCO 3]

40.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology [GCO 1]

39.0 construct arguments to support a decision or judgement, using examples and evidence and recognizing various perspectives [GCO 1]

25.0 develop, present, and defend a position or course of action, based on findings [GCO 2]

43.0 identify and describe science- and technology-based careers related to the science they are studying [GCO 1]

Focus for Learning

Students should

- describe DNA sequencing and explain the historical importance of the Human Genome Project;
- demonstrate an understanding of genetic technologies that amplify, sort, edit, and analyze DNA, including, but not limited to, recombinant DNA, restriction enzymes, polymerase chain reaction (PCR), gel electrophoresis, CRISPR, and DNA microarray;
- describe examples of genetically engineered biotechnology products (i.e., medicinal bacteria, transgenic plants, cloned and transgenic animals); and
- analyze the risks and benefits to society and the environment of genetic research and genetically engineered biotechnology products.

Students are expected to research social, environmental, and ethical issues associated with application of a specific genetic technology (e.g., human gene therapy, genetically modified foods, personal genomics). They should take a position on the use of a specific genetic technology and construct arguments to support and defend their position.

SCOs 25.0 should be assessed as part of this activity. Additionally, teachers may assess skill outcomes 7.0, 8.0, and 26.0. Refer to the *Integrated Skills* unit for elaboration of these outcomes.

Readdress SCO 43.0; identifying and describing careers related to genetics (e.g., genetic counsellor, animal breeder, bioethicist, biotechnologist, forensic laboratory assistant, geneticist).

Attitude

Encourage students to

- appreciate that the applications of science and technology can raise ethical dilemmas;
- project the personal, social, and environmental consequences of proposed action; and
- consider further studies and careers in science- and technology-related fields. [GCO 4]

Sample Performance Indicators

1. Construct arguments to support an assigned position (i.e., for or against) regarding personal genome sequencing or the labelling of genetically modified foods. Defend your assigned position in a debate.
2. Complete Activity 15.6 (*NL Biology*, p. 610) to interpret a DNA fingerprint.

Genomics and Genetic Technologies

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Present videos, sourced online, explaining the Human Genome Project.
- Facilitate a cooperative jigsaw activity, for students to research genetic technologies that amplify, sort, edit, and analyze DNA.
- Facilitate Activity 15.5 (*NL Biology,* p. 610) to model the use of restriction enzymes and DNA ligases to create recombinant DNA.
- Facilitate a class discussion regarding social and ethical issues associated with genome research.

Students may

- Add genomic- and genetic technology-related terminology to their visual dictionary.
- Complete the STSE case study (*NL Biology*, pp. 574-575) to analyze the risks and benefits to society of gene therapy applications.
- Complete the STSE case study (*NL Biology*, pp. 618-619) to analyze the risks and benefits to society and the environment of genetically modified organisms.
- Complete the STSE connections (*NL Biology*, p. 620) to assess the unintended consequences to society of introducing a new biotechnology.

Consolidation

Students may

- Research current and potential future applications of genomics and genetic technologies and analyze the risks and benefits to society and the environment.

Extension

Students may

- Research the concept of “biohacking” and communicate their learning to peers.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 5 pp. 27, 37-38
- Unit 5 pp. 45-49

NL Biology (SR)

- pp. 607-621
- p. 594
- pp. 574-575

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Genetic technologies resources
- Genetic engineering/ Biotechnology products resources

Section Three:
Specific Curriculum Outcomes

Unit 3: Evolutionary Change and Biodiversity

Focus

Science attempts to provide an explanation for the origin and evolution of life on Earth. Students will examine evidence supporting the theory of evolution by natural selection, causes of gene pool change, and the principles underlying taxonomy and phylogeny. The unit will culminate with examination of evolutionary trends evident in animal anatomy and physiology.

This unit emphasizes the nature of science and technology and highlights the unifying concepts of similarity and diversity.

Outcomes Framework

GCO 1 (STSE): Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

43.0 identify and describe science- and technology-based careers related to the science they are studying
45.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge
48.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced
52.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of invention of a technology
63.0 describe the importance of peer review in the development of scientific knowledge
68.0 compare the risks and benefits to society and the environment of applying scientific knowledge or introducing a technology

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

60.0 analyze evolutionary mechanisms and their effects on biodiversity
61.0 describe historical and cultural contexts that have changed evolutionary concepts
62.0 compare different explanations for changes in populations over time
64.0 evaluate and describe evidence to support the theory of evolution by natural selection
65.0 describe how species evolve
66.0 compare and contrast models describing the pace of evolution
67.0 describe how the Hardy-Weinberg principle is used to determine whether a population is undergoing microevolution
69.0 demonstrate an understanding of the fundamental principles of taxonomy
70.0 examine and describe the anatomy and physiology of representative organisms, identifying and describing evolutionary milestones and trends

GCO 2 (Skills): Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

1.0 design an experiment identifying and controlling major variables
2.0 state a prediction and a hypothesis based on available evidence and background information
3.0 evaluate and select appropriate instruments for collecting evidence
4.0 develop and implement appropriate sampling procedures
5.0 use instruments effectively and accurately for collecting data
6.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data
7.0 use library and electronic research tools to collect information on a given topic
9.0 select and use apparatus and materials safely
10.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials
11.0 describe and apply classification systems and nomenclatures used in the sciences
12.0 identify limitations of a given classification system and identify alternative ways of classifying to accommodate anomalies
13.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
15.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
16.0 evaluate the relevance, reliability, and adequacy of data and data collection methods
18.0 explain how data support or refute the hypothesis or prediction
22.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
23.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
26.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise

GCO 4 (Attitudes): Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Students are encouraged to

- value the contributions to scientific and technological development made by individuals from many societies and cultural backgrounds
- confidently evaluate evidence and consider alternative perspectives, ideas, and explanations
- use factual information and rational explanations when analyzing and evaluating
- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

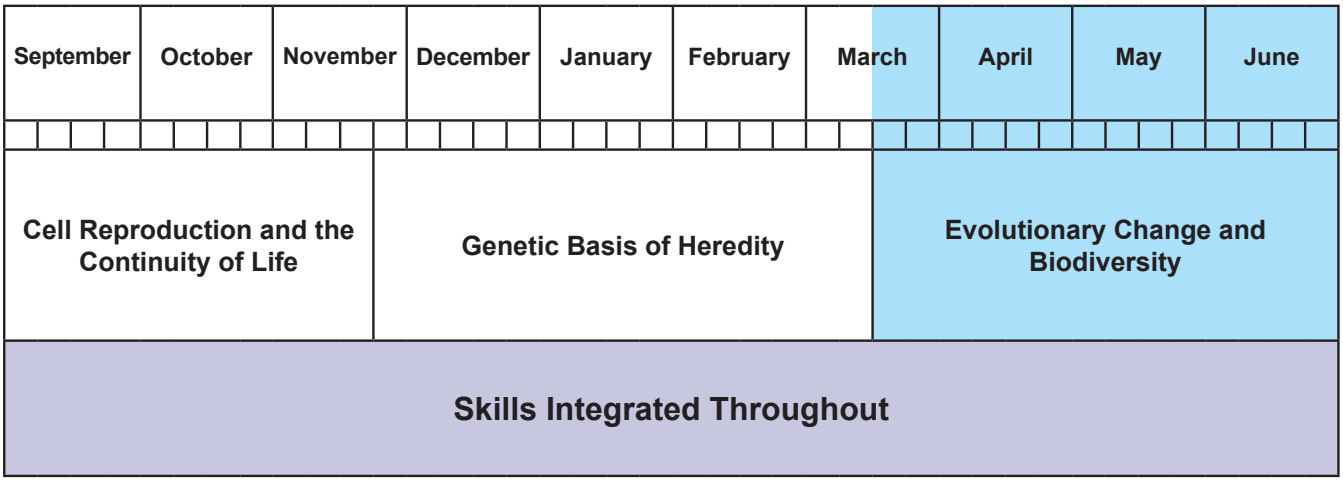
SCO Continuum

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

Science 1206	Biology 2201	Biology 3201
Sustainability of Ecosystems	*Ecosystem Interactions and Population Dynamics*	*Evolutionary Change and Biodiversity*
• explain why ecosystems with similar characteristics can exist in different geographical locations • explain various ways natural populations are kept in equilibrium and relate this equilibrium to the resource limits of an ecosystem • illustrate and explain the cycling of matter through biotic and abiotic components of an ecosystem by tracking carbon, nitrogen, and oxygen • describe the mechanisms of bioaccumulation and explain its potential impact on the viability of and diversity of consumers at all trophic levels • analyze the impact of external factors on an ecosystem • explain how the biodiversity of an ecosystem contributes to its sustainability • explain why different ecosystems respond differently to short-term stresses and long-term changes	• analyze interactions within and between populations • use the concept of the energy pyramid to explain the production, distribution, and use of food resources • compare Canadian biomes in terms of climate, vegetation, physical geography, and location • describe population growth and explain factors that influence population growth • evaluate Earth's carrying capacity, considering human population growth and its demands on natural resources	• analyze evolutionary mechanisms and their effects on biodiversity • describe historical and cultural contexts that have changed evolutionary concepts • compare different explanations for changes in populations over time • evaluate and describe evidence to support the theory of evolution by natural selection • describe how species evolve • compare and contrast models describing the pace of evolution • describe how the Hardy-Weinberg principle is used to determine whether a population is undergoing microevolution • demonstrate an understanding of the fundamental principles of taxonomy • examine and describe the anatomy and physiology of representative organisms, identifying and describing evolutionary milestones and trends

Suggested Unit Plan

The Biology 3201 curriculum concludes with the *Evolutionary Change and Biodiversity* unit.



Variation and Adaptation

Outcomes

Students will be expected to

60.0 analyze evolutionary mechanisms and their effects on biodiversity [GCO 3]

60.1 analyze the effects of genetic variation and natural selection on biodiversity

1.0 design an experiment identifying and controlling major variables [GCO 2]

3.0 evaluate and select appropriate instruments for collecting evidence [GCO 2]

4.0 develop and implement appropriate sampling procedures [GCO 2]

5.0 use instruments effectively and accurately for collecting data [GCO 2]

6.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data [GCO 2]

16.0 evaluate the relevance, reliability, and adequacy of data and data collection methods [GCO 2]

22.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others [GCO 2]

Focus for Learning

The ecological concepts of species and populations were addressed in Science 1206 and Biology 2201.

Evolution is a contentious concept for the members of some cultures and should be addressed with sensitivity. Evolutionary theory, however, is accepted by the scientific community; accounting for the diversity of life on Earth and explaining why life keeps changing.

Students should

- define evolution as the relative change in genetic traits of populations that occurs over successive generations, include microevolution and macroevolution;
- describe how adaptations (i.e., structural, behavioural, physiological) develop as a result of gradual change in the genetic traits of members of a population over time, and improve the chances of survival and reproduction; and
- describe how crossing over in meiosis, sexual reproduction, and mutation result in genetic variation within populations.

Students are expected to personally design and carry out investigations to measure variation in inherited traits within two populations. The focus should be developing detailed procedures and using appropriate tools to collect accurate, reliable measurements. Investigation 16.A (*NL Biology,* p. 638) provides a suggested procedure.

These investigations provide an opportunity to assess a significant number of skill outcomes. In addition to SCOs 1.0, 3.0, 4.0, 5.0, 6.0, 16.0, and 22.0, teachers may also assess skill outcomes 2.0, 13.0, 15.0, 19.0, 23.0, 26.0, and 27.0. Refer to the *Integrated Skills* unit for elaboration of these outcomes.

Attitude

Encourage students to work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas. [GCO 4]

Sample Performance Indicator

Create a formal lab report for the personally designed and conducted investigations to measure variation in inherited traits within two populations (Note, the *NL Science 10* student resource [p. 381] provides a suggested format for a formal report of an experiment).

Variation and Adaptation

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present images or videos, sourced online, depicting the diversity of species on Earth and introduce evolution as a scientific theory which accounts for this diversity.
- Ask students to record an answer to the question “What do you believe evolution is?”
- Use a place mat activity to elicit student preconceptions of evolution.
- Present multiple definitions of evolution that include common misconceptions and ask students to identify the correct definition.

Connection

Teachers may

- Create a class word wall of unit terminology.
- Present an image depicting several individual members of the same species. Ask students to identify differences in their phenotypes.
- Ask students to identify examples of human traits that display variation.
- Provide examples of structural, behavioural, and physiological adaptations evident in local plants and animals.
- Review rules for use of significant digits when measuring (i.e., including all definite digits and estimating the first unknown digit [Appendix A, p. 138]).

Students may

- Create a personal visual dictionary (print or digital) of unit terminology.
- Hypothesize how an adaptation improves an organism’s chances of reproduction and survival (e.g., peeling bark of birch trees).
- Research and identify adaptations of a plant or animal species and explain how they improve their chances of survival and reproduction.
- Complete Activity 16.4 (*NL Biology,* p. 654) to hypothesize the adaptive significance of variations in the structure of hair.

Consolidation

Students may

- Present data from their investigations in tables and graphs and calculate mean, median, mode, and range of their data.
- Use computer software to compile, organize, and graph their data.

Resources and Notes

Authorized

NL Biology
(Teacher Resource [TR])

- Unit 6 pp. 1-7
- Assessment Checklist 1 Designing an Experiment
- Assessment Checklist 2 Laboratory Report

NL Biology
(Student Resource [SR])

- pp. 630-639

Teaching and Leaning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/teaching-and-learning-strategies.html
  - Pilot Teacher Conversations

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Evolution resources
- Science supply companies

Other Curriculum Resources

- *NL Science 10* (Science 1206)

Notes

The magnifying glass icon is used throughout the unit to indicate investigations.

Natural Selection

Outcomes

Students will be expected to

60.0 analyze evolutionary mechanisms and their effects on biodiversity [GCO 3]

60.1 analyze the effects of genetic variation and natural selection on biodiversity

15.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables [GCO 2]

Focus for Learning

Students should

- explain the process of artificial selection, describing examples and discussing its impact on genetic diversity;
- explain the process of natural selection;
- explain how local environmental conditions exerting selective pressure on populations may result in extirpation or extinction; and
- analyze data for and describe examples of natural selection within populations, including, but not limited to, industrial melanism in peppered moths and antibiotic resistance in bacteria.

Analyzing data showing how traits change with the passage of time, as a result of natural selection, provides an opportunity to address skill outcome 15.0. Refer to the *Integrated Skills* unit for elaboration.

Attitude

Encourage students to use factual information and rational explanations when analyzing and evaluating. [GCO 4]

Sample Performance Indicators

1. Black goldendoodle dogs are produced through artificial selection. Describe how this might be achieved.
2. Explain how consistently using a fishing net with a mesh size of 15 cm^2 might change a cod population over the passage of time.
3. As a result of climate change, polar bears are expanding their range into more southern environments. Predict how, over the passage of time, this might change the phenotypes of polar bears or lead to extirpation or extinction.
4. Analyze changes in beak depth of a Galapagos finch species and correlate changes in the finch population to changes in the environment (*NL Biology*, p. 641).

Natural Selection

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Describe how broccoli, cauliflower, cabbage, and kale were all produced from the wild mustard plant through the process of artificial selection.
- Present images showing the diversity of Galapagos finches. Ask students to identify similarities and differences among them and hypothesize what might have led to these changes.
- Discuss the origin and survival of new traits in a population.

Students may

- Add selection-related terminology to their visual dictionary.
- Engage in online simulations of natural selection (e.g., peppered moth game).
- Describe examples of artificial and natural selection.

Consolidation

Teachers may

- Facilitate an activity modelling beak diversity using various utensils (e.g., micro-tweezers, tweezers, chop sticks, salad tongs, barbecue tongs). Ask students to attempt to pick up various sizes of seeds and nuts using the different utensils. Students may then relate beak size and shape to different food sources and explain how these adaptations might be advantageous.

Students may

- Complete Activity 16.1 (*NL Biology*, p. 640) to investigate the ability of bacteria to adapt to quickly changing environmental conditions.
- Compare the processes of artificial selection and genetic engineering as ways of developing organisms with desired traits.

Extension

Students may

- Consider how genetic engineering might impact natural selection.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 6 pp. 5-9

NL Biology (SR)

- pp. 636-642

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Artificial and natural selection resources

Developing the Theory of Evolution by Natural Selection

Outcomes

Students will be expected to

61.0 describe historical and cultural contexts that have changed evolutionary concepts
[GCO 3]

45.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge
[GCO 1]

48.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced
[GCO 1]

62.0 compare different explanations for changes in populations over time
[GCO 3]

63.0 describe the importance of peer review in the development of scientific knowledge
[GCO 1]

Focus for Learning

Examining the development of scientific knowledge to explain how populations change over time provides a context to address the nature of science.

Students should

- recognize that by the sixteenth century the predominant paradigm in western culture was that all species of organisms came into existence at the same time and remained unchanged;
- describe the significance of the following individuals in the development of the theory of evolution by natural selection:
  - Georges-Louis Leclerc (Comte de Buffon),
  - Mary Anning,
  - Georges Cuvier (include catastrophisim),
  - Charles Lyell (include uniformitarianism),
  - Jean Baptiste Lamarck (include acquired characteristics),
  - Charles Darwin and Alfred Wallace, and
  - Thomas Malthus (include competition);
- examine Darwin's observations and recognize how it led to his theory of natural selection; and
- compare Lamarck's and Darwin's explanations for changes in populations over time (Activity 16.3, *NL Biology*, p. 649).

The publication and review of Darwin's work in the 19th Century provides a context to address the importance of peer review in the development of scientific knowledge (Debating Science, *NL Biology*, pp. 668-669). This context also provides opportunity to discuss how science does not exist in a vacuum and how some debates move beyond the bounds of science into the public forum. Parallels may be found with current public debates surrounding climate change and the importance of preserving biodiversity.

Additionally, SCO 42.0, analyze society's influence on scientific endeavours, may be readdressed.

Attitude

Encourage students to value the contributions to scientific and technological development made by individuals from many societies and cultural backgrounds. [GCO 4]

Sample Performance Indicators

1. Create an annotated timeline depicting the contributions of individuals leading to the development of the theory of evolution by natural selection.
2. Darwin was unaware of the work of Mendel during his lifetime. How might knowledge of Mendel's inheritable factors have impacted Darwin's work? What does this say about how scientific knowledge develops?

Developing the Theory of Evolution by Natural Selection

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Review how scientific theories are developed (i.e., hypotheses, extensive observations, experiments) to challenge the non-scientific view that they are “only theories” and therefore not to be believed.

Connection

Teachers may

- Present videos, sourced online, depicting the development of Darwin’s theory of evolution by natural selection.
- Discuss how scientific research is analyzed within the scientific community.
- Describe examples where inadequate peer review leads to negative societal impacts (e.g., vaccination as a cause of autism myth).

Students may

- Distinguish between catastrophism and uniformitarianism.

Consolidation

Students may

- Create a podcast interviewing an individual of significance in the development of the theory of evolution by natural selection.
- Design a social media page for an individual of significance in the development of the theory of evolution by natural selection.
- Discuss how acceptance of the theory of evolution by natural selection represents a paradigm shift.
- Explain why natural selection is considered a scientific theory and not a scientific law.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 6 pp. 9-11, 18

NL Biology (SR)

- pp. 643-649
- pp. 668-669

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Developing a theory resources
- Charles Darwin resources

Evidence of Evolution

Outcomes

Students will be expected to

64.0 evaluate and describe evidence to support the theory of evolution by natural selection [GCO 3]

45.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge [GCO 1]

15.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables [GCO 2]

43.0 identify and describe science- and technology-based careers related to the science they are studying [GCO 1]

Focus for Learning

Students should evaluate and describe evidence supporting the theory of evolution by natural selection including

- the fossil record, including index fossils, radiometric dating, and transitional fossils (Note, students are not expected to solve radiometric dating problems);
- biogeography examples;
- comparative anatomy, including homologous structures, analogous structures, convergent evolution, and vestigial structures;
- comparative embryology, and
- molecular biology and genetics, including DNA and protein comparisons.

Additionally, students should analyze and interpret various geologic time scales and make inferences. Note, students are not expected to memorize time scale content.

The significance of the Ediacaran and Cambrian periods to animal evolution should be addressed.

Evaluating evidence supporting the theory of evolution by natural selection provides an opportunity to readdress SCO 43.0; identifying and describing science- and technology-based careers related to these diverse fields.

Attitude

Encourage students to confidently evaluate evidence and consider alternative perspectives, ideas, and explanations. [GCO 4]

Sample Performance Indicators

1. Research and compare the anatomy, embryology, and other characteristics of harp seals, leatherback sea turtles, and Atlantic puffins to infer and defend which two species are most closely related.
2. Complete Activity 16.5 (NL Biology, p. 656) comparing amino acid sequences from different species and inferring evolutionary relationships among them.

Evidence of Evolution

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present videos, sourced online, that describe the fossil record and connect fossils to current species through the process of evolution.

Connection

Teachers may

- Facilitate a cooperative jigsaw activity to allow students to evaluate and describe evidence of evolution.
- Provide examples of index and transitional fossils.
- Explain the process of radiometric dating and describe how fossil dating led to the development and evolution of the geologic time scale.

Students may

- Add new terminology to their visual dictionary.
- List and explain different scientific fields that have contributed evidence to the theory of evolution by natural selection.
- Provide examples of animals that exhibit convergent evolution.

Consolidation

Students may

- Describe how theories of evolution have changed over time.
- Research local fossils and identify where they fit on geologic time scales. What can be inferred about their environment and evolutionary relationships to other species?
- Differentiate between homologous and analogous structures.

Extension

Students may

- Investigate mass extinction events that mark geologic time scale boundaries.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 6 pp. 11-15

NL Biology (SR)

- pp. 649-658

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Evidence of evolution resources
- Science supply companies

Speciation and the Pace of Evolution

Outcomes

Students will be expected to

65.0 describe how species evolve
[GCO 3]

66.0 compare and contrast models describing the pace of evolution
[GCO 3]

Focus for Learning

Students should

- explain ways in which species become reproductively isolated, including geographic and biological barriers;
- distinguish among pre-zygotic (i.e., behavioural isolation, ecological/habitat isolation, temporal isolation, mechanical isolation, and gametic isolation) and post-zygotic (i.e., hybrid inviability, hybrid sterility, and hybrid breakdown) mechanisms;
- describe how new species form (i.e., transformation, divergence [adaptive radiation]).
- describe how closely associated species may co-evolve; and
- describe gradualism and punctuated evolution models and recognize that both models are at work.

Sample Performance Indicators

1. Severe flooding results in a river changing course. Would you expect a species of mouse that now lives on both sides of the river to eventually become two separate species? What about a species of bird that lives on both sides of the river?
2. Refer to Figure 16.24 (*NL Biology*, p. 664). Interpret the speciation of the woodpecker finch and the large ground finch.
3. Refer to Figure 16.25 (*NL Biology*, p. 664). How might adaptive radiation explain the speciation of the red crossbill?
4. Discuss how climate change might impact speciation and the pace of evolution.

Speciation and the Pace of Evolution

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present images of a liger and a mule. Ask students what they have in common. Direct them toward the answer that both are sterile and cannot be classified as species.

Students may

- Define species and revisit their personal definition after the concept of speciation has been addressed.

Connection

Teachers may

- Present videos, sourced online, describing examples of speciation.
- Present examples of reproductive barriers and ask students to classify them as pre- or post-zygotic and geographic or biological.
- Present Figure 17.23 (*NL Biology*, p. 703). Discuss how these species might have co-evolved.
- Discuss Darwin's finches (*NL Biology*, p. 664) as an example of divergence (adaptive radiation).

Students may

- Add speciation-related terminology to their visual dictionary.
- Consider how wildfires might impact speciation and the pace of evolution.

Consolidation

Students may

- Debate whether Earth might currently be experiencing an era of punctuated equilibrium.
- Discuss how transformation and divergence might impact biodiversity.
- Discuss how the process of speciation might be analogous to the formation of a new language.
- Discuss whether you would expect to find more unique species on a large remote island or a smaller island close to a continent.

Extension

Students may

- Research polar bear - grizzly bear hybrids and relate to speciation.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 6 pp. 1-12

NL Biology (SR)

- pp. 659-667

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Speciation resources

The Hardy-Weinberg Principle

Outcomes

Students will be expected to

67.0 describe how the Hardy-Weinberg principle is used to determine whether a population is undergoing microevolution
[GCO 3]

2.0 state a prediction and a hypothesis based on available evidence and background information
[GCO 2]

13.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
[GCO 2]

15.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
[GCO 2]

18.0 explain how data support or refute the hypothesis or prediction
[GCO 2]

23.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
[GCO 2]

Focus for Learning

Students should

- define population genetics and gene pool;
- distinguish among genotype frequency, phenotype frequency, and allele frequency;
- describe the gene pool of a population at genetic equilibrium;
- summarize the five conditions upon which the Hardy-Weinberg principle is based;
- use Hardy-Weinberg equations to solve problems related to allele, genotype, and phenotype frequencies in a population, as well as the number of individuals with specific genotypes and phenotypes (Note, students should be familiar with various forms of allele notation); and
- interpret data to determine whether a population is undergoing microevolution.

Students are expected to conduct an investigation to determine the effect of random mating on a large population, as well as the effect of a lethal recessive allele on allele frequencies in a large population. The focus should be on the analysis of individual and class data. Investigation 17.B (*NL Biology*, p. 684) provides a suggested procedure. Coloured beans may be used as an alternative to beads.

In addition to SCOs 2.0, 13.0, 15.0, 18.0, and 23.0, teachers may assess SCOs 6.0, and 16.0. Refer to the *Integrated Skills* unit for elaboration.

Attitude

Encourage students to value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not. [GCO 4]

Sample Performance Indicators

1. In a population that is in Hardy-Weinberg equilibrium, the frequency of the dominant allele *A* is 0.7. What percentage of individuals show the dominant trait?
2. In a population of 800 mice that is in Hardy-Weinberg equilibrium, 128 mice express the recessive black fur trait. How many of the mice are heterozygous for fur colour?
3. Would a Newfoundland Pine Marten population achieve Hardy-Weinberg equilibrium? Explain.
4. Is a population that is at genetic equilibrium evolving? Explain.
5. Imagine that the first human mission to Mars was a success. A self sustaining colony was established consisting of 3 females and 6 males, all of reproductive age. Identify reasons why this population would not achieve genetic equilibrium according to the Hardy-Weinberg principle.

The Hardy-Weinberg Principle

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present videos, sourced online, of birds engaged in courtship displays. Then, use the launch lab (*NL Science*, p. 675) to demonstrate the effect of mate selection on the traits of bird populations.

Connection

Teachers may

- Present videos, sourced online, explaining the Hardy-Weinberg principle and conditions that disrupt Hardy-Weinberg equilibrium resulting in evolution.
- Present data tables depicting examples where allele and genotype frequencies remain the same or change over several generations.

Students may

- Add population genetics-related terminology to their visual dictionary.
- Explore population genetics online simulations.
- Consider whether it is possible to have a population that never evolves.
- Carry out Investigation 17.A (*NL Biology*, p. 682); applying the Hardy-Weinberg equation to analyze frequencies of human genetic characteristics.

Consolidation

Students may

- Practice solving Hardy-Weinberg problems (*NL Biology*, BLM 17.1.2).
- Create Hardy-Weinberg problems for classmates to solve.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 6 pp. 1-12
- BLM 17.1.2

NL Biology (SR)

- pp. 674-686

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Hardy-Weinberg resources

Causes of Gene Pool Change

Outcomes	Focus for Learning
Students will be expected to	
60.0 analyze evolutionary mechanisms and their effects on biodiversity [GCO 3] 60.2 analyze causes of gene pool change	Students should • identify and compare the effects of genetic mutations, gene flow, non-random mating (i.e., sexual selection, inbreeding), genetic drift, and natural selection on gene pool diversity; • distinguish between founder and bottleneck effects; • distinguish among stabilizing, directional, and disruptive selection and analyze and interpret graphs to identify the type of natural selection; and • examine examples of how human activities (e.g., commercial fishing, habitat loss, invasive species, over harvesting, dam/road construction, climate change, selective hunting, insecticide/herbicide use, antibiotic/antimicrobial cleaner use) affect the genetic diversity of natural populations.
68.0 compare the risks and benefits to society and the environment of applying scientific knowledge or introducing a technology [GCO 1]	Students are further expected to analyze the risks and benefits to society and the environment of genetic engineering technologies (e.g., artificial selection, transgenic organisms, cloning) through the lens of evolution (e.g., *NL Biology,* p. 698). They should select a biotechnology of personal interest and consider how its use might impact the gene pools of domesticated and wild populations of organisms (e.g., Will biotechnology result in the evolution of new species? Does biotechnology have the potential to impact wild populations? Can biotechnology help preserve species?). **Sample Performance Indicators** 1. Describe the impact of repeated inbreeding on gene pool diversity. 2. DNA analysis of cheetah populations show little or no genetic variation among individuals. Does this evidence suggest the possibility of a bottleneck effect or a founder effect? Explain. 3. Hummingbirds insert their bill into flowers to drink nectar. Assume that bill length varies within a population and shows a normal distribution. Describe scenarios that might result in directional, stabilizing, and disruptive selection. Illustrate how each type of selection might alter the distribution graph in subsequent generations.

Causes of Gene Pool Change

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Facilitate a cooperative jigsaw activity to address causes of evolutionary change (i.e., genetic mutations, gene flow, non-random mating, genetic drift, natural selection).
- Present videos, sourced online, depicting causes of gene pool change.
- Discuss the gene causing sudden heart attacks, known as Newfoundland's curse, as an example of founder effect.
- Provide examples of the factors that cause change in allele frequencies (e.g., Warfarin-resistance in Norway rats [mutation], grey wolf migration [genetic drift], antler sparring among male caribou [sexual selection], self-fertilization in pea plants [inbreeding], polydactylism in Amish populations [founder effect], and lack of genetic diversity in northern elephant seals [bottleneck effect]).

Students may

- Add gene pool-related terminology to their visual dictionary.
- Engage with online simulations depicting gene pool change and genetic drift (i.e., founder and bottleneck effects).
- Research to identify examples of populations that have evolved as a result of one of the causes of evolutionary change.
- Analyze graphs depicting stabilizing, directional, and disruptive types of natural selection.

Consolidation

Students may

- Complete Activity 17.1 (*NL Biology*, p. 690) to apply the Hardy-Weinberg equation to a new situation.
- Complete Activity 17.2 (*NL Biology*, p. 696) to investigate factors effecting the genetic diversity of local threatened species.
- Discuss the potential impact of wildlife corridors on gene pool diversity.
- Consider how accidental release of genetically modified salmon from an ocean pen might impact the gene pool of wild populations.

Extension

Students may

- Research Newfoundland's unique mitochondrial DNA and describe it as an example of the founder effect.
- Research genetic conditions being studied in Newfoundland and Labrador.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 6 pp. 1-12

NL Biology (SR)

- pp. 687-698

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Gene pool change resources
- Effects of biotechnology resources

Biological Classification

Outcomes

Students will be expected to

69.0 demonstrate an understanding of the fundamental principles of taxonomy
[GCO 3]

11.0 describe and apply classification systems and nomenclatures used in the sciences
[GCO 2]

12.0 identify limitation of a given classification system and identify alternative ways of classifying to accommodate anomalies
[GCO 2]

9.0 select and use apparatus and materials safely
[GCO 2]

22.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
[GCO 2]

52.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology
[GCO 1]

Focus for Learning

Students should

- recognize that Earth's biodiversity can be explained both by genetic changes in populations over time and by major evolutionary changes that produce new species;
- explain how Earth's biodiversity can be classified into taxa (i.e., domain, kingdom, phylum, class, order, family, genus, species);
- define, explain the need for, and apply binomial nomenclature;
- identify distinguishing features among the three domains and among the four Eukarya kingdoms (i.e., prokaryotic/eukaryotic, unicellular/multicellular, cell wall presence and composition [peptidoglycan, chitin, cellulose], nutritional method, motility, reproductive strategy);
- explain how viruses challenge biological classification (characteristics of life); and
- examine and evaluate technologies used for specimen identification, including, but not limited to, dichotomous keys, field guides, and mobile device applications.

Students are expected to use dichotomous keys to identify specimens. Note, developing a key is not an expectation. These investigations provide opportunities to assess skill outcomes 9.0, 11.0, 12.0, and 22.0. Refer to the *Integrated Skills* unit for elaboration of these SCOs.

Students should recognize that biological classification systems change as new understandings of organisms emerge; often as a result of the invention of a technology. They should analyze and describe how advances in microscopy and genetic and molecular analyses revealed key differences among organisms and how the classification system was subsequently modified to better explain these differences.

Attitude

Encourage students to confidently evaluate evidence and consider alternative perspectives, ideas, and explanations. [GCO 4]

Sample Performance Indicators

1. A field survey has discovered a previously unknown species. What distinguishing features would help classify the unknown species as belonging to the Eukarya domain and Kingdom Fungi?
2. Why might it be beneficial for all biologists to use the same classification system?

continued

Biological Classification

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present examples of classification systems used in everyday life.

Connection

Teachers may

- Present early biological classification systems and their limitations.
- Present collections of microscope slides representing bacteria, protists, fungi, and plants for students to examine (Note, students who have not completed Biology 2201 may require instruction in how to view a prepared slide [*NL Biology*, pp. 722-726]).
- Model how to create a simple dichotomous key for a group of objects (e.g., backpacks, beads, buttons, nuts and bolts, shoes).
- Provide various field guides and dichotomous keys for students to use in identifying specimens.
- Discuss how some species challenge taxonomic categories.

Students may

- Carry out Investigation 1.A (*NL Biology*, p. 15) to practice using taxon nomenclature.
- Represent defining features of domains and kingdoms in a table.
- Use field guides and mobile device applications (e.g. *Leafsnap*, *PlantSnap, PictureThis, Picture Insect, iNaturalist*) to identify local specimens (e.g., plants, birds, or insects).

Consolidation

Teachers may

- Facilitate Activity 17.3 (*NL Biology,* p. 701) to reinforce students' understanding of taxonomy and classification.
- Provide a collection of physical specimens or images from different taxonomic groups. Ask students to examine and group them based on their features, explaining their thinking aloud.

Students may

- Discuss the importance of using binomial nomenclature.
- Identify and discuss limitations of classification systems and technologies used to identify specimens.
- Discuss what changing biological classification systems as new evidence emerges says about the nature of science.
- Explore the utility of bioinformatics (i.e., DNA barcode database) as a biological classification system (*NL Biology*, p. 704).

continued

Resources and Notes

Authorized

NL Biology (TR)

- Unit 1 pp. 1-12

NL Biology (SR)

- pp. 11-16
- p. 704

Teaching and Leaning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/teaching-and-learning-strategies.html
  - Dichotomous Keys and Dissection

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Biological classification resources
- Science supply companies

Biological Classification

Outcomes

Students will be expected to

69.0 demonstrate an understanding of the fundamental principles of taxonomy
[GCO 3]

11.0 describe and apply classification systems and nomenclatures used in the sciences
[GCO 2]

12.0 identify limitation of a given classification system and identify alternative ways of classifying to accommodate anomalies
[GCO 2]

9.0 select and use apparatus and materials safely
[GCO 2]

22.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
[GCO 2]

52.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology
[GCO 1]

Focus for Learning

3. Use the information in the table below to answer the following
   - Which two organisms would you expect to share the greatest number of features?
   - Which two species are least similar to the Siamese Cat?
   - What evidence is there that otters share more features with mink than cats and dogs?
   - Infer why biologists might group river otters, American mink, Siamese cats and Labrador retrievers in the same order.
   - Predict some probable features of *Alopex lagopus.*
   - Use the scientific name of one organism to explain binomial nomenclature.

Common Name	Order	Family	Scientific Name
orca	Cetacea	Delphinidea	*Orcinus orca*
little brown bat	Chiroptera	Vespertilionidae	*Myotis lucifugus*
river otter	Carnivora	Mustelidae	*Lontra canadensis*
American mink	Carnivora	Mustelidae	*Neovison vison*
Siamese cat	Carnivora	Felidae	*Felis domesticus*
Labrador retriever	Carnivora	Canidae	*Canis lupus*
	Carnivora	Canidae	*Alopex lagopus*

Biological Classification

Sample Teaching and Assessment Strategies

Extension

Students may

- Create a dichotomous key for a group of specimens.
- Research the use of subtaxa in classification (e.g., subspecies).

Resources and Notes

Authorized

NL Biology (TR)

- Unit 1 pp. 1-12

NL Biology (SR)

- pp. 11-16
- p. 704

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Biological classification resources
- Science supply companies

Phylogeny - Evolutionary Classification

Outcomes

Students will be expected to

69.0 demonstrate an understanding of the fundamental principles of taxonomy
[GCO 3]

48.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced
[GCO 1]

12.0 identify limitation of a given classification system and identify alternative ways of classifying to accommodate anomalies
[GCO 2]

2.0 state a prediction and a hypothesis based on available evidence and background information
[GCO 2]

7.0 use library and electronic research tools to collect information on a given topic
[GCO 2]

13.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
[GCO 2]

26.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
[GCO 2]

Focus for Learning

Students should

- describe the macroevolution of Bacteria, Archaea, Protists, Fungi, Plants, and Animals from an original cell, include endosymbiosis;
- recognize that phylogeny classifies organisms based on evolutionary relatedness, using homologous structures, fossil records, and genetic and molecular analyses as evidence;
- analyze and interpret evolutionary trees (i.e., infer relationships [most recent common ancestor, more closely related groups], identify clades, identify shared derived characters).

Students should recognize that evolutionary trees are hypotheses that are tested with evidence and subject to change as new evidence emerges. Expose students to various styles and orientations of evolutionary trees. Ensure they understand that rotating a branch around its node does not change the depicted relationship.

Note, the terms cladogram and phylogenetic tree are not used consistently within the scientific community, therefore, for the purposes of this course, the term evolutionary tree is used.

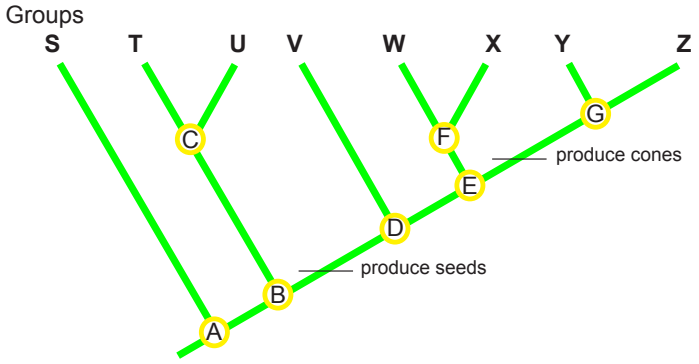
Students are expected to engage in research to describe the features of different taxonomic groups, infer shared derived characters, and make hypotheses about their evolutionary relationships. Activity 17.4 (*NL Biology*, p. 702) provides a suggested procedure. Students should represent hypothesized relationships in an evolutionary tree.

In addition to SCOs 2.0, 7.0, 13.0, and 26.0, teachers may assess 6.0, 8.0, and 11.0. Refer to the *Integrated Skills* unit for elaboration.

Sample Performance Indicator

Answer the questions for the evolutionary tree below.

- What is the most recent common ancestor of groups Y and U?
- To which other groups is V most closely related?
- How many different clades are represented in this diagram?
- Explain why groups S, T, U, and their ancestors are not a clade.
- Which groups do not produce cones?



Phylogeny - Evolutionary Classification

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present images of a simplified tree of life representing the macroevolution of major groups of organisms.

Connection

Teachers may

- Present examples of various styles and orientations of evolutionary trees (e.g., *NL Biology,* pp. 13, 664, 700, 701, 710).
- Present terminology related to evolutionary trees (e.g., root, branch, node, clade).
- Present videos, sourced online, explaining how to analyze and interpret evolutionary trees.
- Present videos, sourced online, explaining how evolutionary trees are constructed from tables of shared derived characters.
- Model the creation of an evolutionary tree (BLM 17.3.3) by identifying features of different taxonomic groups, inferring shared derived characters, and hypothesizing relationships.

Students may

- Compare and contrast pedigree charts and evolutionary trees.
- Practice analyzing and interpreting evolutionary trees, sourced online.

Consolidation

Students may

- Revisit the distinguishing features of the three domains and four eukaryotic kingdoms and annotate a simplified tree of life (e.g., Figure 17.20, *NL Biology*, p. 700), placing derived characters at the appropriate locations.
- Construct an evolutionary tree from a provided table of taxonomic groups and shared derived characters.

Resources and Notes

Authorized

NL Biology (TR)

- Unit 6 pp. 1-12
- BLM 17.3.3

NL Biology (SR)

- pp. 699-705

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Evolutionary tree resources

Anatomy and Physiology - Non-Chordates

Outcomes

Students will be expected to

70.0 examine and describe the anatomy and physiology of representative organisms, identifying and describing evolutionary milestones and trends
[GCO 3]

9.0 select and use apparatus and materials safely
[GCO 2]

10.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials
[GCO 2]

22.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
[GCO 2]

26.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
[GCO 2]

Focus for Learning

Students should identify and describe features used as evidence when classifying and hypothesizing evolutionary relationships among non-chordate animal groups (i.e., Porifera, Cnidaria, Platyhelminthes, Rotifera, Annelida, Mollusca, Arthropoda, Nematoda, Echinodermata), including, but not limited to,

- presence of specialized tissues (i.e., nerves);
- body plan symmetry (i.e., asymmetry, radial, bilateral);
- embryonic cell layers (i.e., monoblastic, diploblastic, triploblastic);
- coelom presence (i.e., acoelomate, pseudocoelomate, eucoelomate);
- embryonic development pattern (i.e., protostome, deuterostome);
- one- and two-opening digestive systems;
- cephalization;
- motility;
- segmentation;
- and molting.

Students are expected to investigate the anatomy and physiology of non-chordate animals, identifying and describing evolutionary milestones and trends, through

- examination of live or preserved specimens of representative animals (e.g., sea anemone, hydra, planaria, earthworm, philodina, tapeworm, snail, mussel, sea star, sea urchin, grasshopper, beetle, butterfly, crab);
- examination of prepared slides of representative animals and their structures (e.g., sponge, hydra, daphnia, planaria, earthworm, ascaris, hookworm, tapeworm, drosophila, leeches); and
- dissection of preserved or fresh specimens of representative animals (e.g., earthworm, grasshoppers, scallop, mussel, squid, crayfish, crab, sea star, sea urchin, sea cucumber).

Note,

- firsthand dissections are the expectation, however, for individual students who object or have cultural or ethical concerns, virtual dissection or video should be used as an alternative; and
- students who have not completed Biology 2201 may require instruction in microscope use (*NL Biology,* pp.722-726).

Students' safe use of microscopes, dissection tools, and personal protective equipment, proper handling and disposal of specimens, and communication and cooperation within groups should be assessed. Skill outcomes 5.0, 23.0, and 27.0 may also be assessed.

Refer to the *Integrated Skills* unit for elaboration of these SCOs.

continued

Anatomy and Physiology - Non-Chordates

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present, for student analysis, evolutionary trees depicting the relationships among non-chordate animal groups.

Connection

Teachers may

- Create a wall-sized evolutionary tree to represent relationships among major animal groups. As they are addressed, groups, representative examples, and derived characters can be added to the tree.
- Introduce and model the use of specific terminology when describing features of non-chordate animals.
- Present dissection guides and videos to support firsthand dissections.
- Acquire and care for animal specimens in fresh- and saltwater aquariums and animal terrariums to facilitate student observations and examination of live specimens.
- Facilitate 3D printing of anatomical models of animals.
- Present videos sourced online explaining the evolution of non-chordate animal groups.

Students may

- Differentiate between anatomy and physiology.
- Create an image bank of representative examples of non-chordate animal groups studied.
- Use magnification tools (e.g., hand lenses, stereoscopes, microscopes) to view live and preserved specimens of representative animals.
- Examine physical and virtual models of non-chordate animal anatomy.
- Engage with virtual dissections and videos sourced online.
- Use digital images to record firsthand observations when examining and dissecting specimens of representative animals.

Consolidation

Students may

- Dissect and compare specimens of different echinoderms and different molluscs.

Resources and Notes

Authorized

Teaching and Leaning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/teaching-and-learning-strategies.html
  - Pilot Teacher Conversations
  - Dichotomous Keys and Dissection

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Non-chordate animal anatomy and physiology resources
- Science supply companies

Notes

Non-chordate anatomy and physiology is not addressed in the *NL Biology* authorized resources.

Anatomy and Physiology - Non-Chordates

Outcomes

Students will be expected to

70.0 examine and describe the anatomy and physiology of representative organisms, identifying and describing evolutionary milestones and trends
[GCO 3]

9.0 select and use apparatus and materials safely
[GCO 2]

10.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials
[GCO 2]

22.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
[GCO 2]

26.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
[GCO 2]

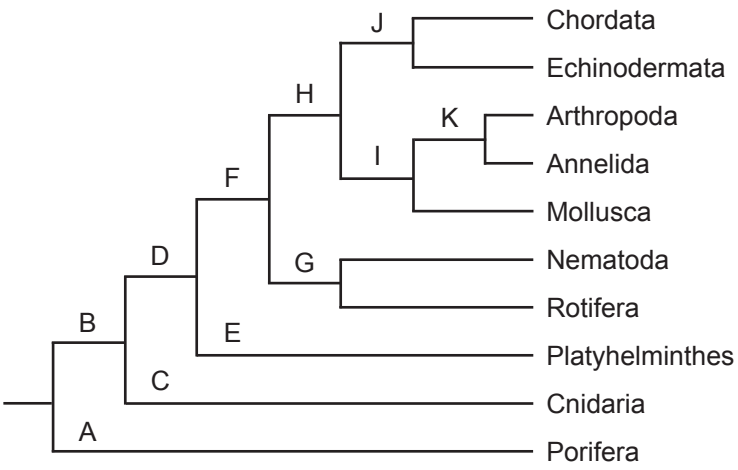
Focus for Learning

Additionally, students should

- identify representative organisms belonging to Porifera, Cnidaria, Platyhelminthes, Rotifera, Annelida, Mollusca, Arthropoda, Nematoda, Echinodermata);
- describe the features and adaptations of specimens investigated;
- explain the significance of evolutionary milestones identified in the anatomy and physiology of non-chordate animals (i.e., bilateral symmetry, triploblastic cell layers, coelom, deuterostome development, two-opening digestive system, cephalization, segmentation); and
- describe evolutionary trends evident in the digestive and nervous systems of non-chordate animals.

Sample Performance Indicator

1. Annotate the evolutionary tree below identifying features that might be used to separate the branches at the identified locations.



2. Explain the evolutionary significance of the coelom.
3. Describe features that might be used when classifying or hypothesizing evolutionary relationships for annelids.
4. Describe evolutionary trends observed in the digestive systems of non-chordate animal groups.

Anatomy and Physiology - Non-Chordates

Sample Teaching and Assessment Strategies

Resources and Notes

Authorized

Teaching and Leaning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/teaching-and-learning-strategies.html
  - Pilot Teacher Conversations
  - Dichotomous Keys and Dissection

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Non-chordate animal anatomy and physiology resources
- Science supply companies

Notes

Non-chordate anatomy and physiology is not addressed in the *NL Biology* authorized resources.

Anatomy and Physiology - Chordates

Outcomes

Students will be expected to

70.0 examine and describe the anatomy and physiology of representative organisms, identifying and describing evolutionary milestones and trends
[GCO 3]

9.0 select and use apparatus and materials safely
[GCO 2]

10.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials
[GCO 2]

22.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
[GCO 2]

26.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
[GCO 2]

Focus for Learning

Students should

- describe features shared by all chordates (i.e., notochord, dorsal hollow nerve cord, pharyngeal slits, post anal tail); and
- identify representative organisms of chordate groups (i.e., cephalochordata, urochordata [tunicata], agnatha, chondrichthyes, osteichthyes, amphibia, reptilia, aves, mammalia).

Students are expected to investigate the anatomy and physiology of chordate animals, identifying and describing evolutionary milestones and trends, through

- examination of live and preserved specimens of representative animals (e.g., sea squirt, lancelet, lamprey, skate, dogfish shark, aquarium fish, trout, tadpole/frog, gecko, turtle, chicken, rat, fetal pig); and
- dissection of preserved or fresh specimens of representative animals (e.g., tunicate, lamprey, hagfish, dogfish shark, herring, skate, frog, chicken, rat, fetal pig).

Note, firsthand dissections are the expectation, however, for individual students who object or have cultural or ethical concerns, virtual dissection or video should be used as an alternative.

In addition to SCOs 9.0, 10.0, 22.0, and 26.0, skill outcomes 5.0, 23.0, and 27.0 may also be assessed. Refer to the *Integrated Skills* unit for elaboration of these SCOs.

Through examination and dissection of representative chordates, students should

- describe the features and adaptations of specimens studied;
- identify and describe features used as evidence when classifying and hypothesizing evolutionary relationships among chordate groups, including
  - braincase (skull), jaws, vertebrae, cartilaginous and bony skeletons, vertebrae;
  - paired limbs (ray-fins, lobed-fins), four limbs (tetrapod), wings (modified forelimbs);
  - skin as a respiratory organ, gills (gill slits, operculum), lungs;
  - ectotherm, endotherm;
  - two-, three-, and four-chambered hearts;
  - external or internal fertilization and development, quantity of eggs produced, amniotic egg (soft shell, hard shell), degree of parental care, mammary glands;
  - scales, waterproof skin, feathers, hair; and
  - cephalization, brain development, complex sense organs;

continued

Anatomy and Physiology - Chordates

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present, for student analysis, evolutionary trees depicting the relationships among major chordate animal groupings.

Students may

- Identify features shared by all chordates.

Connection

Teachers may

- Present images, sourced online, of evolutionary trees depicting evolutionary relationships among chordates.
- Create a wall-sized evolutionary tree to represent relationships among chordates. Groups, representative examples, and derived characters can be added as they are addressed.
- Present dissection videos and documents to guide students in conducting their own firsthand dissections.
- Facilitate 3D printing of anatomical models of animal specimens and specific organs.
- Present videos sourced online explaining the evolution of chordate groups.

Students may

- Add images of representative chordate animals to the image bank previously created.
- Examine physical and virtual models of animal anatomy.
- Engage with vertebrate dissection videos and virtual dissections sourced online.
- Use digital images to record firsthand observations when examining and dissecting specimens of representative animals.

continued

Resources and Notes

Authorized

Teaching and Leaning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/teaching-and-learning-strategies.html
  - Pilot Teacher Conversations
  - Dichotomous Keys and Dissection

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Chordate animal anatomy and physiology resources
- Science supply companies

Notes

Chordate anatomy and physiology is not addressed in the *NL Biology* authorized resources.

Anatomy and Physiology - Chordates

Outcomes

Students will be expected to

70.0 examine and describe the anatomy and physiology of representative organisms, identifying and describing evolutionary milestones and trends
[GCO 3]

9.0 select and use apparatus and materials safely
[GCO 2]

10.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials
[GCO 2]

22.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
[GCO 2]

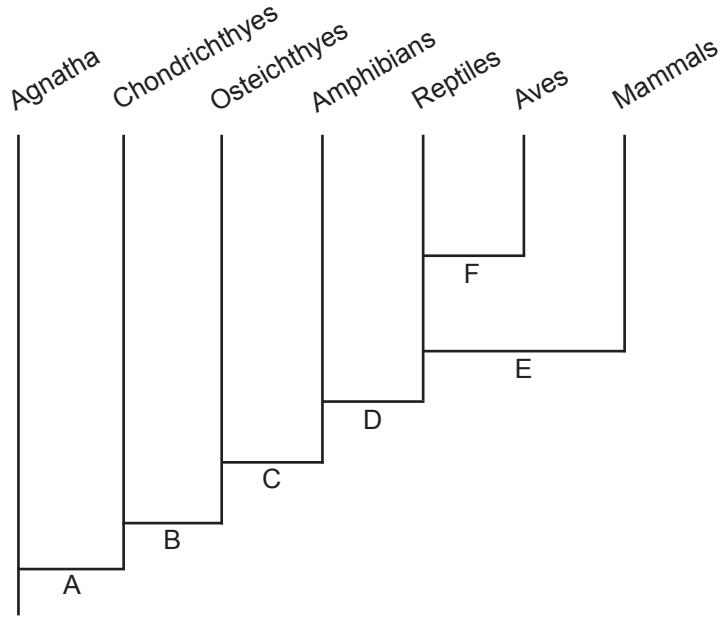
26.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
[GCO 2]

Focus for Learning

- describe evolutionary trends evident in chordate skeletal, respiratory, circulatory, nervous, and reproductive systems; and
- describe evolutionary milestones that enabled life to move from water to land.

Sample Performance Indicators

1. Annotate the evolutionary tree below identifying derived characters that might have been used to separate the branches at the identified locations.



2. Describe the anatomy and physiology of bony fish with reference to their skeletal, respiratory, circulatory, and reproductive systems.
3. Explain the evolutionary significance of lobed-fins.
4. Describe the advantage of a four-chambered heart.
5. Using examples, explain the evolution of reproductive systems, evident in chordate groups.
6. Describe how life on land is evident in the anatomy and physiology of reptiles.

Anatomy and Physiology - Chordates

Sample Teaching and Assessment Strategies

Consolidation

Students may

- Represent the key evolutionary characters of major vertebrate animal groupings in an appropriate format.
- Discuss the evolution of the lung from amphibians to mammals and the heart from osteichthyes to mammals.

Extension

Students may

- Analyze and interpret evolutionary trees representing human evolution.

Resources and Notes

Authorized

Teaching and Leaning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/teaching-and-learning-strategies.html
  - Pilot Teacher Conversations
  - Dichotomous Keys and Dissection

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/biology-3201/resource-links.html

- Chordate animal anatomy and physiology resources
- Science supply companies

Notes

Chordate anatomy and physiology is not addressed in the *NL Biology* authorized resources.

Appendix A:
Scientific Conventions

Scientific Conventions

Scientific information should be communicated according to accepted scientific conventions. These conventions include significant figures, formulas, units, and data (graphs, diagrams, tables). The Department of Education follows the conventions below for public exams.

Significant Figures

Any number used in a calculation should contain only figures that are considered reliable; otherwise, time and effort are wasted. Figures that are considered reliable are called significant figures. Scientific calculations generally involve numbers representing actual measurements. In a measurement, significant figures in a number consist of:

Figures (digits) definitely known + one estimated figure (digit)

They are often expressed as “all of the digits known for certain plus one that is uncertain”.

Significant Figure Rules

1. All non-zero digits are significant.
2. Zero rules
   - Trailing zeros (i.e., at the end to the right) of a measurement may or may not be significant:
     - If it represents a measured quantity, it is significant (e.g., 25.0 cm - the zero is significant; the decimal is clearly indicated).
     - If immediately to the left of the decimal, it is not significant (e.g., 250 cm or 2500 cm - zeros are not significant; both have 2 significant digits as there is uncertainty whether zeros are measured values).
     - If the trailing zeros in 250 cm and 2500 cm are significant, the measurements must be written in scientific notation (e.g., 2.50×10^2 cm or 2.500×10^3 cm - zeros are significant). Note, scientific notation is not part of the K-12 mathematics program.
   - A zero, between two non-zero digits in a measurement, is significant (e.g., 9.04 cm - the zero is significant).
   - Leading zeros (i.e., at the beginning to the left) are never significant (i.e., they do not represent a measured quantity), they merely locate the decimal point (e.g., 0.46 cm and 0.07 kg - the zeros are not significant).
3. Rounding with Significant Figures

   In reporting a calculated measured quantity, rounding an answer to the correct number of significant figures is important if the calculated measurement is to have any meaning. The rules for rounding are listed below.
   - If the figure to be dropped is less than 5, eliminate it:
     - rounding 39.949 L to three significant figures results in 39.9 L
     - rounding 40.0 g to two significant figures results in 4.0×10^1 g
   - If the figure to be dropped is greater than or equal to 5, eliminate it and raise the preceding figure by 1:
     - rounding 39.949 L to four significant figures results in 39.95 L
     - rounding 39.949 L to two significant figures results in 4.0×10^1 L

4. Multiplying and Dividing with Significant Figures

   In determining the number of significant figures in a measurement that is calculated by multiplying or dividing, the measurement with the least number of significant figures should be identified. The final calculated measurement should contain the same number of significant figures as the measurement with the least number of significant figures.

   $$2.1 \text{ cm} \times 3.24 \text{ cm} = 6.8 \text{ cm}^2$$

   Since 2.1 cm contains two significant figures and 3.24 contains three significant figures, the calculated measurement should contain no more than two significant figures.

5. Adding and Subtracting with Significant Figures

   In determining the number of significant figures when adding or subtracting, the final calculation should be rounded to the same precision as the least precise measurement.

   $$42.56 \text{ g} + 39.460 \text{ g} + 4.1 \text{ g} = 86.1 \text{ g}$$

   Since 4.1 g has only one decimal place, the calculated measurement must be rounded to one decimal place.

6. Performing a Series of Calculations with Mixed Operations

   When a series of calculations is performed, it is important to remember that multiplication/division and addition/subtraction are governed by separate significant figure rules. Rounding only occurs at the last step.

   When calculations involve both of these types of operations, the rules must be followed in the same order as the operations. Rounding still only occurs at the last step of the calculation.

   $$\frac{(0.428 + 0.0804)}{0.009800}$$

   The addition is first, 0.428 + 0.0804 = 0.5084. Following the rules for addition/subtraction, the answer should have three significant figures, but rounding is the last step. Therefore, 0.5084 is used in the next step, 0.5084 ÷ 0.009800 = 51.87755. Following the rules for multiplication/addition, the answer should have four significant figures (but rounding is the last step). The sum of the numerator has three significant figures, and the denominator has four, so the final answer is rounded to three significant figures, 51.9.

   In problems requiring multiple calculations (e.g., calculating final velocity and then using that value to calculate time), it is recommended that rounding only occur in the final calculation. Also, to improve accuracy and consistency, an extra digit should be carried in all intermediate calculations. Students may find it helpful to write the extra digit as a subscript (e.g., 39.5_4 [3 significant figures + 1 extra].

7. Calculating with Exact Numbers

   Sometimes numbers used in a calculation are exact rather than approximate. This is true when using defined quantities, including many conversion factors, and when using pure numbers. Pure or defined numbers do not affect the accuracy of a calculation. You may think of them as having an infinite number of significant figures. Calculating with exact numbers is important when dealing with conversions or calculating molar ratios in chemistry.

8. Scientific Constants

   Treat scientific constants as significant digits because they are rounded values (i.e., actual measured or defined values have many decimal places [e.g., the speed of light constant, 3.00×10^8 m/s, is a rounded value based on the defined value, 299 792 458 m/s]).

9. Significant Figures in Logarithms

   When determining the number of significant figures from a logarithm function, only the digits to the right of the decimal should be counted as significant figures.

   - What is the pH of a sample of orange juice that has 2.5×10^{-4} mol/L hydronium ions?
     The measurement 2.5×10^{-4} mol/L has two significant figures. The power of ten indicates where the decimal is located (i.e. 0.00025). The pH of the sample is $-\log(2.5 \times 10^{-4}) = 3.602\ 059$. The digit to the left of the decimal is derived from the power of ten, therefore, it is not significant. Only two digits to the right of the decimal are significant. The answer should be recorded as 3.60.
   - What is the hydronium ion concentration of orange juice with pH = 2.25?
     The pH value, 2.25, has two significant figures. The hydronium ion concentration is equal to the antilogs of -2.25. This value is 0.0056234 mol/L, which, when rounded to two significant figures, becomes 0.0056 mol/L or 5.6×10^{-3} mol/L.

Formulas and Units

A constructed response question that requires numerical calculations often uses formulas or equations as the starting point to its solution. Proper use of formulas and units in science indicates a thorough understanding of the logic to solve a problem. For any solution that requires the mathematical manipulation of a formula, the formula should be stated at the beginning, followed by workings that clearly indicate the mathematical computations necessary to find the solution.

For most cases in science, a SI unit follows a measured value because it describes the value. Three exceptions to this are pH, equilibrium constants, and index of refraction. The final answer of a solution for a constructed response question that requires the mathematical manipulation of a formula always has a unit with the value. The workings of a solution that lead to the final answer do not have to show units.

Data

Data is generally presented in the form of graphs, tables, and drawings. When these formats are used several scientific conventions should be followed.

Graphs

Graphs represent relationships between numerical information in a pictorial form. Two kinds of graphs are commonly used in science courses in Newfoundland and Labrador:

- Line graph
  - used to display the relationship between continuous data
  - demonstrates a progression of values or shows how one variable changes in relation to another variable (e.g., growth of a child with age)

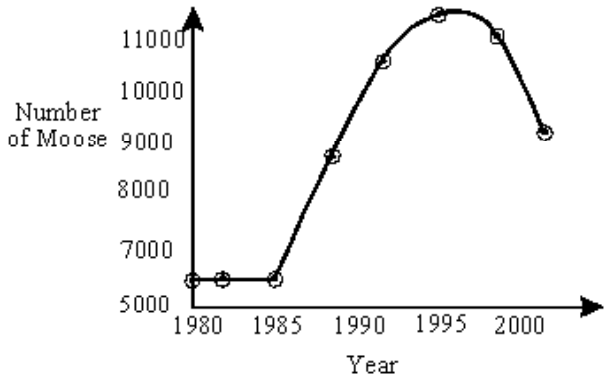
  Note: When equations are graphed, a line or curve of best-fit must be drawn.

- Bar graph
  - used to display discrete or discontinuous data
  - consists of parallel bars whose lengths are proportional to quantities given in a set of data. The items compared are plotted along the horizontal axis and appropriate measurement is plotted along the vertical axis (e.g., populations of different types of protists in a lake).

Graphing Rules

1. The graph must have a title. The title represents the relationship between the two variables.
2. The independent variable is on the horizontal *x*-axis.
3. The dependent variable is on the vertical *y*-axis.
4. Each axis is specifically labelled with units (if applicable) according to the variable it represents and values are provided with equal increments. The scale does not have to be the same on both axes, but the scales must accommodate the ranges of the two variables (i.e., the graph line or series of bars must fill ≥ 75% of the available space).
   Note: It is not necessary that both axes start at zero. See example below.
5. When data are plotted, a circle should be placed around each point to indicate a degree of error. The graph may show exact numbers or a general relationship. A best-fit line or curve must be used in line and scatter graphs.
6. A legend may be used to identify individual lines on a multi-line graph.

Moose Population in Newfoundland and Labrador (1980 - 2000)



Tables

Tables represent numerical or textual information in an organized format. They show how different variables are related to one another by clearly labelling data in a horizontal or vertical format. As with graphs, tables must have a title that represents the relationship between the variables.

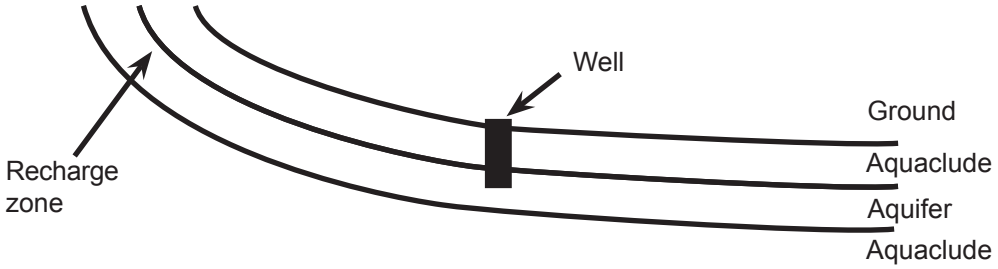
Moose Populations in Newfoundland and Labrador (1980 - 2000)

Year	Number of Moose
1980	5789
1985	6057
1990	8823
1995	11 156
2000	9315

Drawings

Biological drawings that indicate a scale are not required. Diagrams, however, may often be used to aid explanations. These should be clear and properly labelled to indicate important aspects of the diagram.

Geological Conditions Necessary for an Artesian Well



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