PROGRAM OF STUDY

BIOLOGY

Subject Area: Mathematics, Science and Technology

Adult General Education

DBE
Diversified Basic Education

Québec

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Introduction

1.1 Contribution of the Subject to the Education of Adult Learners

As an integral part of the societies it helped to shape, science represents both an important aspect of their cultural heritage and a key factor in their development. The rapid emergence of large amounts of complex scientific knowledge and the proliferation of its applications presume that people should possess a fund of specific knowledge as well as strategies for freeing themselves of the constraints inherent in change. This requires that they see the achievements of science in perspective, understand the scope and limitations of this knowledge and be able to evaluate their impact. For this reason, science is not the preserve of a small group of experts.

As with all scientific disciplines, biology provides adult learners with tools that help them understand the world around them. It calls upon them to widen their cultural horizons and become more aware of how this culture can help them make informed decisions, and it gives them the opportunity to acquire knowledge through scientific activity. This activity arouses curiosity, imagination and a willingness to explore. In addition to helping learners discover the joy of experimentation, scientific activity satisfies their need to understand, explain and create.

Biology is all around us every day. A great number of contributions have been made in this field in terms of innovations and applications. Examples include improvements in healthcare, birth control and gene sequencing. A new form of agriculture based on genetically defined properties has revolutionized livestock and crop production, which has had an impact on our diet. The ethical and moral issues raised by such developments are often the subject of public debate and discussion. Understanding the concepts underlying such issues helps adult learners evaluate the scientific information presented in the media and make sound decisions for themselves, their loved ones and future generations.

The Secondary V *Biology* program is a continuation of the scientific education offered as part of the Common Core Basic Education program in Secondary III and IV. It is intended to consolidate and enrich adult education, more specifically in the areas of health and well-being, and the environment. The general concepts are grouped into two largely interdependent broad areas: Applied Genetics and Reproduction and Development. The concepts are addressed using learning situations that deal with contemporary problems and issues related to biology.

1.2 Approach to the Subject

Science is a means of analyzing the world around us. Its aim is to describe, explain and predict certain phenomena and events of our universe. Consisting of a series of observations, concepts, laws, theories, models and methods, it is characterized by its attempt to develop simple, intelligible models to explain our complex world. Theories and models are used to predict certain phenomena. As we construct new knowledge, these theories and models are constantly being tested, modified and reorganized. For example, the theory of evolution changed over time in response to our understanding of the mechanisms of evolution and genetics. Similarly, cell theory was refined in part as a result of progress in microscopy. Scientific activity and its resulting applications can have a major impact, both positive and negative, which we must learn to take into account.

Biology is the study of the structure, function, reproduction and diversity of living beings and the relationships that develop among them. It is at the crossroads of several subject fields, such as physics, chemistry, geography and climatology. Technology, particularly biotechnology, drives its development. Biology has its own vocabulary and symbols and occasionally uses mathematical language.

As with most scientific disciplines, biology has experienced phenomenal growth in recent decades. Previously confined to botany, zoology and anatomy, biology is now increasingly present in the fields of biotechnology, molecular biology and ecology.

1.3 Connections Between the Subject and the Other Elements of the Diversified Basic Education Program

The *Biology* program is connected to the other components of the Diversified Basic Education Program, such as the broad areas of learning, the cross-curricular competencies and the other subject areas.

1.3.1 Connections With the Broad Areas of Learning

The broad areas of learning are divided into five areas of life: *Health and Well-Being*, *Environmental Awareness and Consumer Rights and Responsibilities*, *Media Literacy*, *Career Planning and Entrepreneurship*, and *Citizenship and Community Life.* The Secondary V *Biology* program uses learning situations pertaining to these broad areas of learning. In this way, adult learners are able to see that their learning is related to their various everyday activities.

Health and Well-Being

The knowledge that students acquire in studying biology can provide answers to many questions

related to how the body works, the perpetuation and development of life and the treatment of certain diseases. The learning situations related to this broad area of learning encourage adult learners to reflect on the consequences of their actions and lifestyle on the environment, their health and the health of their loved ones. This can help them take care of their own well-being and, if necessary, change the way they use health care services.

Environmental Awareness and Consumer Rights and Responsibilities

Many advances in biology have changed consumer habits and have led to various consequences for the environment. For example, communities are now more likely to face problems associated with the presence of antibiotics, antibiotic-resistant bacteria or synthetic hormones in aquatic ecosystems. In addition, through hybridization, cloning and genetic modifications, it is now possible to produce food crops that grow faster, require fewer pesticides and have a longer shelf life. But the presence of genetically modified organisms in the food supply and in the environment raise a number of questions. By delving deeper into these topics, adult learners can enhance their understanding of issues pertaining to biodiversity and be better able to make consumer choices that reflect their values and priorities.

Media Literacy

Adults use the various media to learn, obtain information and communicate, which is why it is important that they develop a critical view of the information they receive and pass on. Movies, newspapers, television and various other electronic media address topics related to biology. A strong grounding in science is useful for assessing the reliability of information.

Career Planning and Entrepreneurship

Many employment sectors require a grounding in biology. For this reason, the tasks that adult learners will carry out in this program offer opportunities for them to better understand the work of people employed in sectors that involve biology. In this way, adult learners will be able to become acquainted with scientific work, develop their interests, measure their aptitudes for such trades and occupations and consider a career in this field.

Citizenship and Community Life

The competencies developed and the knowledge acquired in studying biology lead to a new perspective on social issues. Various problems such as those associated with the quality of food, the cost of healthcare, vaccination, contagion, the protection of certain habitats, animal welfare and the development of assisted reproductive technologies can provide opportunities to learn about responsible citizenship. Adult learners can thus improve the quality of their participation in society in general.

1.3.2 Connections With the Cross-Curricular Competencies

The development of scientific literacy involves the acquisition and then development of three subject-specific competencies which, in turn, contribute to the acquisition of the more general cross-curricular competencies. These are grouped in several categories, reflecting different facets of the ability to act.

Intellectual Competencies

The learning situations in this program require that adult learners *use information* judiciously and question the reliability of their sources. The search for answers or solutions enables them to acquire *problem-solving skills* that they can then apply in other situations. Adult learners *use creativity* and *exercise critical judgment* when analyzing scientific texts or presentations or when evaluating the consequences of biology.

Methodological Competencies

The attention to precision associated with the methods used in biology requires that adult learners *adopt effective work methods*. They *use information and communications technologies*, which provide them with access to a wider variety of information sources and means of action.

Personal and Social Competencies

Adult learners who move from the abstract to the concrete or from decision to action, and who are willing to take risks *achieve their potential*. In biology, the development of knowledge is based on the sharing of ideas or points of view, and peer or expert validation. In these contexts, adult learners are encouraged to *cooperate with others*.

Communication-Related Competency

The assimilation of new concepts and their representations through mathematical, scientific and technical language increases the adult learners' capacity to *communicate appropriately*. They must not only become familiar with the vocabulary, codes and conventions of biology, but must also learn to use them adequately.

1.3.3 Connections With the Other Subject Areas

Each subject addresses an object of study from the perspective of its own frame of reference. From an interdisciplinary perspective, it is important to connect the learning achieved in biology with that acquired in other subjects. In this way, other subjects can shed light on biology just as biology can, in turn, help us gain a better understanding of other subjects.

Mathematics, Science and Technology

The programs of study in Mathematics, Science and Technology and Computer Science all belong to the same subject area. They target the development of similar subject-specific competencies in terms

of problem solving, reasoning and communication. Other subjects in the subject area make a complementary contribution to biology.

Progress in chemistry and physics has an impact on biology. In chemistry, for example, knowledge of gases, more specifically oxygen, has enabled us to understand the role of respiration in the combustion of nutrients. Moreover, the study of chemical reactions involving degradation and synthesis has shed light on the functioning of enzymes. Lastly, the observation tools used in biology (microscopes) were improved as a result of progress made in physics.

Mathematics also is closely related to the science programs. In fact, most experimental results are presented as graphs and analyzed using statistics. Examples of this include the mathematical simulation of allele frequency in a population to demonstrate its evolution or the graphical analysis of the percentage of individuals who carry or have a genetic disease in a given population. The vocabulary, graphs, notation and symbols used in mathematics constitute a language of rigorous precision biology draws on. Mathematics is frequently used in developing or constructing models and in collecting and processing measurement results. Statistical studies and correlations using mathematics provide a way of extracting data that would be difficult to obtain otherwise. Conversely, biology helps adult learners concretely understand certain mathematical concepts, such as variables, proportional relationships and various functions. It provides meaningful contexts for the study of measurement or statistics.

The computer boom has accelerated the development of knowledge in biology by providing higher-performance tools for finding information, processing data, and presenting and sharing results. Examples include population growth modelling, DNA chips and rapid DNA sequencing. For its part, biology provides contexts for the application of computer science principles, thereby stimulating the creation and development of new products, such as drugs, diagnostic tests and genetically modified organisms.

Languages

The Languages subject area provides essential tools for developing scientific competencies. In biology, an adult learner who interprets information or who describes or explains a phenomenon makes use of competencies developed in the Languages subject area. Biology presents the student with an opportunity to use precise vocabulary and to understand the importance of rigorously accurate language.

Since English is used worldwide in scientific communication, the adult learner who possesses a command of English, as well as of a second or third language, has access to more numerous and diverse sources of information.

Social Sciences

The advances made by science occur in a social and historical setting. The historical perspective places scientific progress in context, enabling adult learners to appreciate the importance of progress

and measure its implications. Similarly, wealth (and its method of distribution) influences both the development of societies and the advancement of knowledge, including biology.

Since societies are dependent on the tools and means at their disposal, the study of biology enables them to see their history and development in a different light.

Arts Education

The subjects in Arts Education contribute substantially to the development of creativity. The *Biology* program draws on this creativity for solving problems. In turn, the study of biology contributes to the arts. For example, a good understanding of the human body can help dancers and actors improve their performances.

Personal Development

The *Biology* program takes into account reflections related to personal development when it encounters questions of an ethical nature, such as issues related to research and the implementation of new medical technologies. As well, the study of living organisms and the conditions needed to sustain life also contributes to personal development. In fact, this knowledge can lead to the adoption of more responsible behaviours.

Career Development

The fields of application for biology touch on numerous sectors of activity and can be associated with the occupations in these sectors. The learning situations proposed in the program of study give adult learners ideal opportunities to explore different work activities and their related occupations. In return, the activities associated with the Career Development programs can help adult learners discover an interest in scientific questions in the field of biology.

Chapter 2

Pedagogical Context

2.1 Learning Situations

Learning situations help adult learners construct and mobilize knowledge and develop subject-specific and cross-curricular competencies. Related to a specific context, they present a problem to be solved or an issue to be examined. They involve one or more tasks leading to the production of a specific piece of work.

Through their context, learning situations help achieve the educational aim of the broad area of learning to which they are related. *Meaningful*, *open* and *complex* learning situations confer more meaning on the knowledge acquired and foster the integration of subject-specific content and key features of the competencies. A learning situation is *meaningful* when it focuses on adult learners' interests as they relate to current events, major social issues, or scientific or technological achievements that affect everyday life. It is *open* when it enables adult learners to choose a method and explore several possible solutions. It is *complex* when it provides adult learners with the opportunity to develop and apply more than one competency and requires them to mobilize a greater number of resources.

Although the use of learning situations is compulsory, none of the examples given in the courses is prescribed. The same applies to examples of tasks. Teachers create or choose those that they deem appropriate.

2.2 Families of Learning Situations

Learning situations that share a resemblance because of the types of tasks they include constitute a family. Whatever their level of complexity, situations in the same family foster the transfer of learning. The *Biology* program consists of two families of learning situations: *Research* and *Expertise*.

The learning situations in the *Research* and *Expertise* families allow for the construction of knowledge, the mobilization of resources, the implementation of investigative processes and the development of the competencies in the Secondary V *Biology* program.

The families of learning situations are compulsory. Every course must include learning situations drawn from the two families described below.

Research

Learning situations in the *Research* family consist of tasks aimed at solving a problem in biology. Such situations promote active learning and help adult learners understand the concepts in biology and apply the knowledge and skills it requires.

These situations also require the use of creativity, rigour and precision. When using an investigative process, adult learners define a problem, establish their action plan or justify the one given to them. They select the tools they need and use them to solve the problem, or they explain the choice of techniques used. Presenting the results of their work provides adult learners with the opportunity to sharpen their research skills and, if applicable, propose new hypotheses or solutions. Situations in this family require adult learners to plan, use scientific equipment or models, analyze and interpret information and share results.

The learning situations in the *Research* family focus on scientific activities, such as laboratory and field experiments, which involve the use of materials and techniques specific to biology. This does not exclude documentary research or modelling, but rather calls upon adult learners to use a variety of information sources to solve a problem.

Expertise

Learning situations in the *Expertise* family involve tasks requiring the analysis of a biological phenomenon or of an application related to biology. Adult learners identify the scientific concepts at play, determine how they work together and explain them. To do so, they must make use of all available information and draw upon concepts, laws, theories or models from the field of biology. Learning situations in this family call upon adult learners to make a decision, formulate a recommendation or make a prediction based on analysis of a biological application or phenomenon. They help them make connections between theoretical concepts and concrete situations; most importantly, they encourage them to consider various points of view, express their opinion and be more responsible.

2.3 Educational Resources

In developing their competencies, adult learners draw on different resources that can be classified as personal, conceptual, informational, material, institutional or human.

Personal resources include knowledge, skills, strategies, attitudes and techniques that adult learners have already acquired. Conceptual resources comprise knowledge acquired in different academic subjects, while informational resources include textbooks, reference documents and any other materials used in searching for information. Material resources can include many types of instruments, tools, machines and objects. Institutional resources refer to public or parapublic organizations, industries or local businesses, and any other community resource. Teachers and classmates are considered to be the most immediately accessible human resources. Laboratory and workshop technicians are good resources, especially where laboratory or workshop safety is concerned. As needed, adult learners can also consult teachers in other subjects or different experts.

Chapter 3

Subject-Specific Competencies

3.1 How the Subject-Specific Competencies Work Together

In the Diversified Basic Education Program, a competency is defined as **the ability to act effectively by mobilizing a range of resources**. It is demonstrated in contexts of a certain complexity, and the degree to which it is mastered may increase throughout a person's education and even lifetime. The Secondary V *Biology* program targets the development of three subject-specific competencies. These competencies are associated with three complementary dimensions of science: practice and methodology, theory and communication.

The first competency, *Seeks answers or solutions to problems involving biology*, is closely related to the *Research* family and emphasizes the methodology used to solve problems in science. It focuses on the mobilization of techniques and concepts associated with biology, primarily within the context of an investigative process that most often takes place in a laboratory.

The second competency, *Makes the most of his/her knowledge of biology*, is closely related to the *Expertise* family and stresses the ability to conceptualize and to transfer learning, especially when analyzing phenomena or applications. It involves the assimilation of concepts in biology leading to an understanding and explanation of these phenomena and applications. It also entails examining the nature of scientific and technological knowledge, its evolution and its social, environmental and economic impact.

The third competency, *Communicates ideas relating to questions involving biology, using the languages associated with science and technology*, is demonstrated by the knowledge and use of specialized terminology and symbols. It draws on the various languages used in biology that are essential to sharing information and to interpreting and producing messages of a scientific nature.

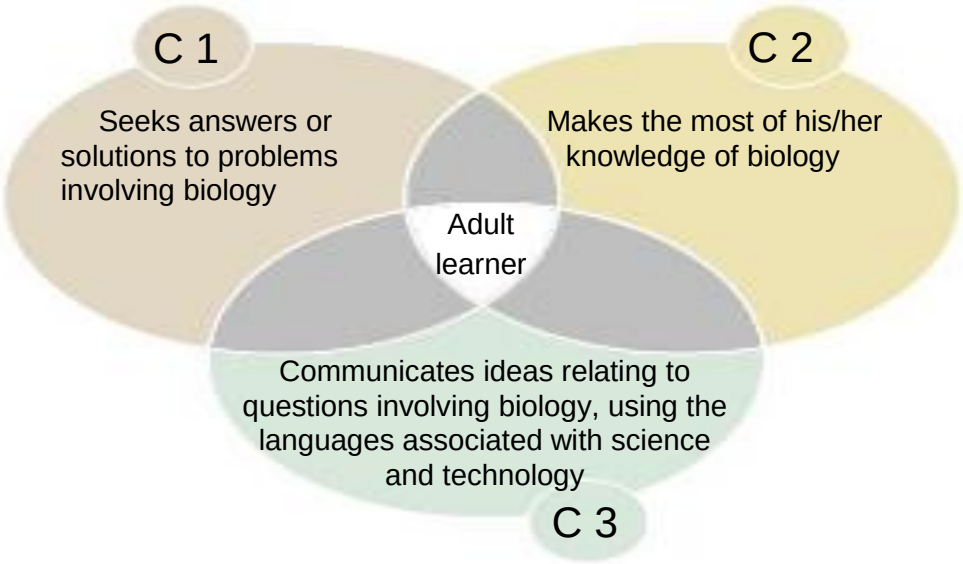


Diagram 1 – How the Subject-Specific Competencies Work Together

The three competencies are interrelated in various ways and are developed in synergy. For example, adult learners cannot seek answers to problems involving biology without learning and applying specific knowledge and mastering communication strategies. Likewise, to make the most of biological knowledge requires using a language shared by the members of the scientific community. This knowledge is applied repeatedly in solving problems.

The Three Aspects of Demonstrating a Competency

A competency is demonstrated through action and is expressed in the satisfactory execution of tasks in a given context. There are three aspects to its demonstration: contextualization, mobilization of resources and reflection.

First of all, applying a competency requires a thoughtful reading of the characteristics of the context, in other words, contextualization. Second, adult learners must take into account any constraints inherent in the context, make a plan and mobilize a set of resources. Lastly, they must be able to explain how they went about mobilizing an appropriate set of resources to act in a given situation. The concept of competency therefore involves the ability to present the steps taken to carry out tasks and solve problems. This reflection process allows adult learners to better adjust their actions and the teachers to adjust their interventions.

Interactions Between the Aspects of Demonstrating a Competency

The three aspects of demonstrating a competency are not a simple juxtaposition of concepts. They interact in a **dynamic** way:

- The interaction between contextualization and the mobilization of resources involves reusing and recombining the same knowledge in a number of ways, depending on the contexts.
- The interaction between reflection and contextualization enables adult learners to perceive more clearly the characteristics of the situation and to better understand its constraints.
- The interaction between reflection and the mobilization of resources primarily involves the reorganization of knowledge. It is also related to any type of analysis that enables adult learners to identify the strengths and weaknesses of the course of action taken.

Each of these interactions contributes to the transfer of learning. The following diagram illustrates how the different aspects of demonstrating a competency work together.

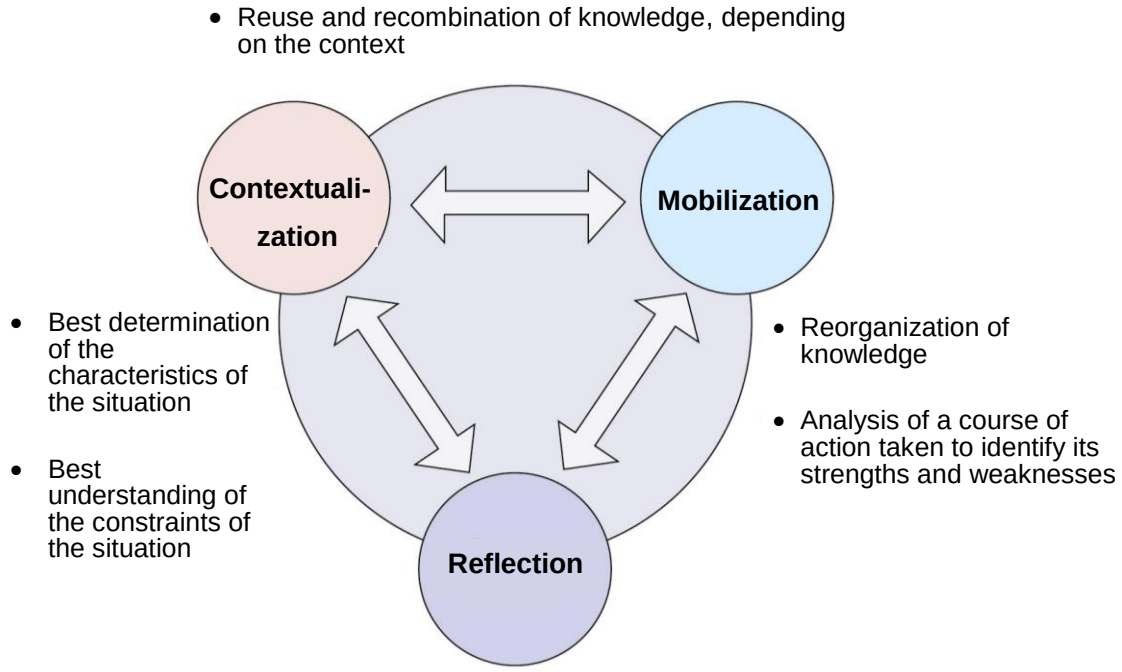


Diagram 2– Interactions Between the Aspects of Demonstrating a Competency

3.2 Competency 1: Seeks answers or solutions to problems involving biology

3.2.1 Focus of the Competency

Like other science subjects, biology is characterized by a rigorous approach to the search for answers or solutions to the problems belonging to its field. The type of reasoning it employs is based on investigative processes that require the mobilization of strategies, techniques and concepts that are grounded in science. The structuring of these resources implies that adult learners are capable of selecting and adapting them to a particular situation. It is by exploring various avenues, testing hypotheses, receiving feedback and reformulating a problem that adult learners will finally be able to construct a solution that is satisfactory without necessarily being the only possible option. Generally speaking, the competency *Seeks answers or solutions to problems involving biology* involves carrying out experiments and requires the use of specialized materials. In the current *Biology* program, it is practised primarily through modelling and documentary research.

The first aspect of this competency becomes evident when adult learners develop a way of representing a problem based on meaningful indicators and relevant elements. This initial representation of the problem may require several adjustments over time.

The representation of the problem is followed by the search for various possible solutions. After a scenario has been selected, a plan of action is developed taking into account applicable material constraints and limitations, as well as the resources available to solve the problem.

Adult learners then implement their plan of action by carrying out the planned procedures and operations, taking care to record all observations that may be useful to them at a later time. The need to obtain new data can mean having to adjust the initial plan or search for more appropriate solutions.

The data collected must then be analyzed. Adult learners identify tendencies and significant relationships, provide relevant explanations and draw conclusions. If applicable, they make a judgment of the accuracy of their results according to the discrepancy they observe in comparison with an acceptable conventional value. These comparisons enable them to validate or invalidate their hypothesis and judge the relevance of their answer.

3.2.2 Key Features and Manifestations of the Competency

- **Defines a problem**
  - Determines the elements that seem relevant
  - Determines the relationships between the different elements
  - Reformulates the problem in terms of biology concepts
  - Formulates realistic hypotheses or possible solutions

- **Develops a plan of action**
  - Chooses a hypothesis or a solution
  - Determines the necessary resources
  - Plans the steps involved in implementing the plan of action

- **Carries out the plan of action**
  - Handles equipment and substances and carries out planned operations
  - Gathers potentially useful data or observations
  - Adjusts the plan of action or its implementation, if necessary

- **Analyzes his/her results**
  - Processes the data gathered or his/her observations
  - Looks for significant patterns or relationships
  - Makes connections between his/her results and biology concepts
  - Judges the appropriateness of the answer or solution found
  - Formulates new hypotheses or solutions, if applicable

3.2.3 Development of the Competency

Biology is the search for answers to questions about phenomena that are governed by laws. It makes use of an investigative process that generates theories or models that serve as the basis for understanding these phenomena.

In order to foster the development of the competency *Seeks answers or solutions to problems involving biology,* teachers propose learning situations that require the use of one or more investigative processes and that encourage adult learners' involvement in problem solving. To carry out a plan of action, a certain number of tasks involving modelling, documentary research and laboratory experiments will be used to develop the competency.

Review activities focus on the process used to *Seek answers or solutions to problems involving biology* and encourage better use of the steps in this process. This metacognitive exercise is also applied to the conceptual resources, techniques and strategies used throughout the problem-solving process, as well as to their adaptation to different contexts.

3.3 Competency 2: Makes the most of his/her knowledge of biology

3.3.1 Focus of the Competency

Biology is indispensable for understanding many of the issues in the world today. Adult learners who are able to make the most of their knowledge of biology are better equipped to participate in society and understand their role in it more clearly. To acquire this knowledge, adult learners must use methods of reasoning and investigative processes that they have studied in their biology courses.

The first manifestation of the competency *Makes the most of his/her knowledge of biology* appears when adult learners examine the context of an issue under study. They start by defining the various aspects of the issue and identifying ethical considerations. They subsequently identify any applications or phenomena related to biology.

When analyzing phenomena or applications from a biological point of view, adult learners describe them qualitatively or quantitatively, while also noting and explaining the relevant biological concepts, laws, theories or models and connections between them. They may be asked to carry out certain tasks in the field (e.g. collect samples) or in the laboratory (e.g. use a microscope).

By using the results of their analysis, adult learners are able to develop and justify an explanation of the issue under study. If applicable, they may also make connections with other similar issues.

When adult learners are required to form an opinion on an issue, they gather information on the relevant elements, compare data and points of view, and express and justify their opinion in a precise and coherent manner, taking others' opinions into account.

3.3.2 Key Features and Manifestation of the Competency

❖ **Puts issues in context**

- Defines the contextual aspects of the issue (e.g. social, economic, environmental, historical)
- Identifies ethical considerations associated with the issue
- Determines the phenomena or applications related to biology

❖ **Analyzes a phenomenon or application from a biological point of view**

- Describes a phenomenon or application qualitatively or quantitatively
- Recognizes the biological concepts, laws, theories, principles and models involved in the phenomenon or application
- Explains biological concepts, laws, theories, principles and models
- Makes connections among biological concepts, laws, theories, principles and models

❖ **Explains an issue from the standpoint of biology**

- Develops an explanation based on concepts, laws, theories, principles and models of biology
- If applicable, establishes connections with other issues involving the same elements
- Justifies his/her explanation

❖ **Forms an opinion about an issue**

- Determines the elements that can help him/her form an opinion
- Gathers information on these elements from different sources
- Compares different points of view
- Supports his/her opinion with the elements considered
- Qualifies his/her opinion, taking others' opinions into account

3.3.3 Development of the Competency

To enable adult learners to develop the competency *Makes the most of his/her knowledge of biology*, teachers propose learning situations involving the analysis of one or more issues related to biology.

Using the investigative process to analyze an issue permits adult learners to identify certain relevant scientific principles. In addition, in order to exercise this competency, adult learners need to dispose of the conceptual tools required to understand these principles. To understand and explain an application or phenomenon related to an issue, adult learners must acquire new knowledge and combine it with what they already know. This knowledge can also be used by adult learners to support their opinion about the issue and to debate other biology-related topics.

The metacognitive tasks carried out by adult learners during review activities enable them to think about how they made the most of their knowledge of biology. These review activities also encourage them to organize their conceptual resources and adapt them to the requirements of different contexts.

3.4 Competency 3: Communicates ideas relating to questions involving biology, using the languages associated with science and technology

3.4.1 Focus of the Competency

Communication plays an essential role in the acquisition of scientific knowledge. This knowledge is constructed based on a set of common meanings, the exchange of ideas and results and the negotiation of points of view. The competency *Communicates ideas relating to questions involving biology, using the languages associated with science and technology* cannot be developed in isolation from the other two subject-specific competencies, to whose development it contributes.

In this program, adult learners interpret and produce messages on biology-related questions. In addition to tables, graphs, diagrams, models and equations, these messages involve biology-specific vocabulary and symbols. In fact, there are standards and conventions governing the writing of protocols and reports. Adult learners take these into account when they prepare for a task, search for information, establish a plan of action, write a report or provide an explanation. They also verify the reliability of the sources they consult and respect the intellectual property rights of persons whose ideas they borrow or whose results they make use of.

3.4.2 Key Features and Manifestation of the Competency

- **Interprets scientific and technological messages**
  - Places the message in context.
  - Makes sure the sources are reliable.
  - Selects the elements needed to interpret the message.
  - Grasps the precise meaning of words or statements.
  - Establishes connections between concepts and their graphical or symbolic representations.

- **Produces scientific and technological messages**
  - Structures his/her message.
  - Uses scientific and technological vocabulary.
  - Uses the symbolic or graphical language associated with science and technology.
  - Adheres to established standards and conventions for the different languages.
  - Demonstrates rigour and coherence.
  - Respects intellectual property rights.

3.4.3 Development of the Competency

To enable adult learners to develop the competency *Communicates ideas relating to questions involving biology, using the languages associated with science and technology*, teachers propose learning situations involving various forms of presentations and the use of precise scientific and technological vocabulary. This helps adult learners to make connections between various representations of concepts.

The learning situations related to the first and second competencies generally offer adult learners an opportunity to develop this third competency. In fact, this competency is needed to do a case study, produce or analyze a report, develop or understand a protocol, create observational drawings or construct a model. Situations in which adult learners share their findings, seek answers to questions in a scientific article, present the results of observations or express their opinion on an issue using supporting evidence foster the development of their ability to communicate in a language adapted to biology in keeping with scientific and technological conventions.

Review activities by adult learners encourage better use of strategies for the interpretation and production of scientific messages. This metacognitive task also focuses on the conceptual resources and techniques associated with communication, on their use and on their adaptation to the requirements of the context.

3.5 Processes

To solve a biology problem or study a phenomenon or an application, adult learners use an investigative process. The following diagram illustrates recognized scientific investigative processes. These processes are used for both the *Research* family and the *Expertise* family.

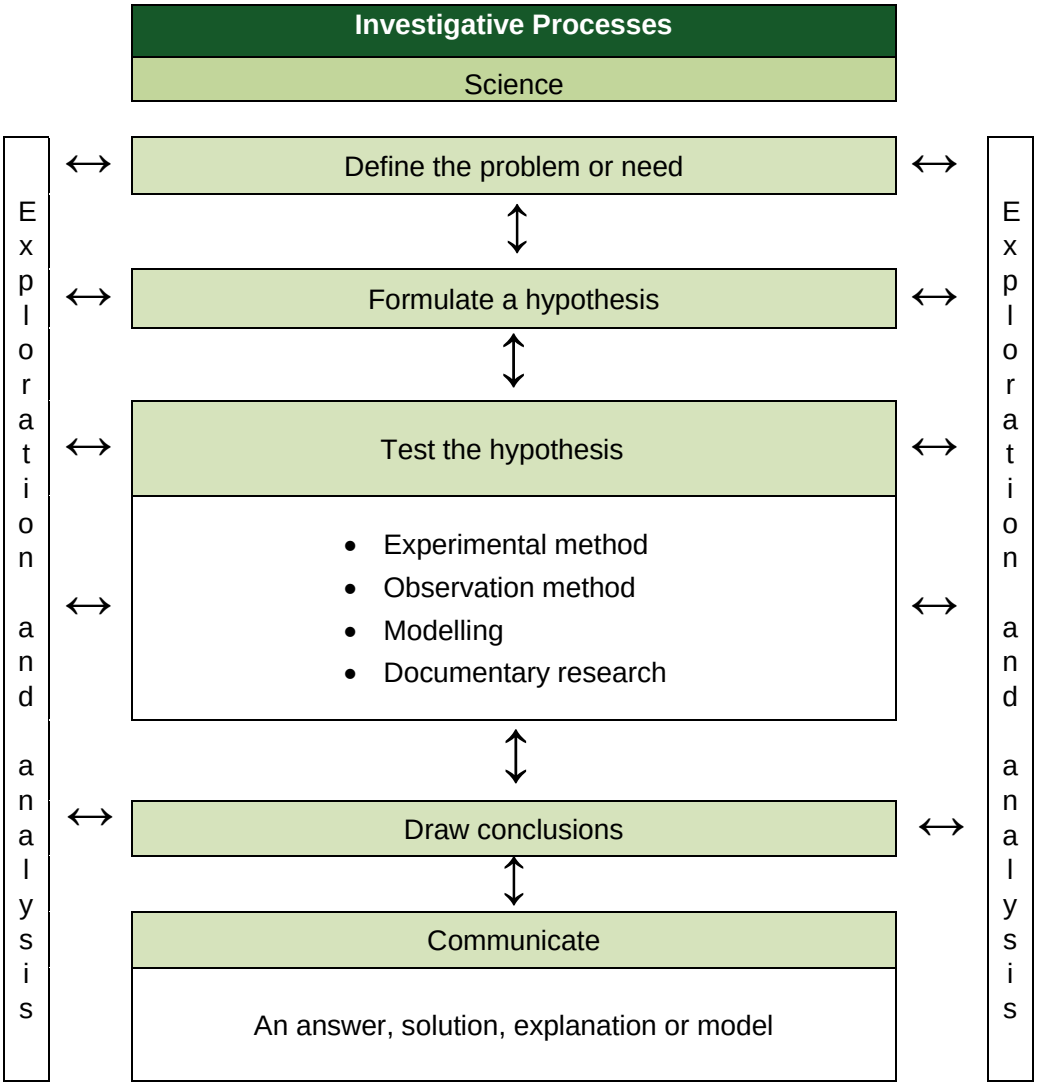


Diagram 3 - Investigative Processes

As suggested by the vertical double-headed arrows, investigative processes are rarely linear. Before adult learners are able to draw conclusions and communicate their solution, they may return several times to a previous step. The horizontal double-headed arrows refer to the exploration and analysis strategies used by adult learners to reach a conclusion more effectively. Examples of each of the strategies and each of the steps are given in Appendices 1, 2 and 3.

The term *investigative processes* encompasses the different methods mentioned in the Secondary Cycle Two programs. These include the experimental method, modelling, the observation method and documentary research. As illustrated in the previous diagram, these processes diverge only at the hypothesis testing stage; that is why, in this program, they are grouped together under the general heading “Investigative Processes.” The tables in Appendix 3 present in detail each of the methods used to test hypotheses.

The *Biology* program gives adult learners the opportunity to use all these methods as they develop both the first and second competency. However, the first competency explicitly draws upon the various methods. Use of the experimental and observation methods helps adult learners understand both the difficulties inherent in scientific research and the work accomplished by scientists who have managed to discover various biological laws and theories despite occasional imprecisions in the measuring instruments they used. In addition, modelling and documentary research are particularly useful when it is difficult to experiment with living matter. Modelling makes it easier to understand an issue and represent and predict certain phenomena, while documentary research assists in the construction of solid arguments supported by facts from reliable sources.

Chapter 4

Subject-Specific Content

4.1 Knowledge

The *Biology* program aims to consolidate and enrich scientific and technological knowledge that is based on the development of competencies and on the construction and mobilization of knowledge, processes, strategies and cultural references. In addition, it aims to train users of biology who are aware of its implications and to prepare some adult learners for careers in the fields of science and technology.

Unlike the Science and Technology, Chemistry and Physics programs, the *Biology* program in the new Diversified Basic Education curriculum is not an adaptation of youth sector programs approved by the Minister.

The *Biology* program is divided into two categories: compulsory concepts and techniques. The program content is based on contemporary issues related to the subject matter and biology programs currently offered in other Canadian provinces. Also included are concepts related to The Living World that are not covered in the Science and Technology programs of the Diversified Basic Education Program.

4.1.1 Compulsory Concepts

The compulsory concepts make up the specific core content of the *Biology* program and are divided into two areas: *The Living World*, which includes the survival of species, and the diversity and maintenance of life; and the *Technological World*, which covers concepts in biotechnology.

The compulsory concepts focus on general concepts related to problems and issues associated with applied genetics as well as those related to reproduction and development in humans, animals and plants. Chapter 6 features more information on the general concepts and a detailed course-by-course list of compulsory concepts and the knowledge to be acquired.

Summary of the Compulsory Concepts for Biology	
The Living World	**The Technological World**

Genetics
• Heredity
• Chromosomes
• Alleles
• Characteristics
• Homozygotes and heterozygotes
• Dominance and recessiveness
• Genotypes and phenotypes
• Mendel's law
  ○ Principle of dominance
  ○ Law of segregation
  ○ Law of independent assortment
• Crossbreeding
  ○ Autosomal inheritance
  ○ Sex-linked inheritance
• Hereditary diseases
 	
Molecular Biology
• Genomes
• DNA replication
• Genes
• Protein synthesis
  ○ Transcription
  ○ Translation
• Genetic code
• Mutations
 	
Evolution
• Biological evolution
• Genetic diversity
• Gene pool
• Mechanisms of microevolution
  ○ Natural and artificial selection
  ○ Genetic flow
  ○ Genetic drift
  ○ Random mating
  ○ Mutation
• Adaptation
• Interventions modifying the genetics of a species
	Genetic Engineering
	• Gene manipulation tools
	• DNA sequencing
	• Genetic engineering applications
	  ○ Cloning
	  ○ Transgenesis
	
	Biotechnology
	• Prenatal diagnoses
	  ○ Genetic testing and screening
	  ○ Diagnostic test
	• Medically assisted procreation
	• Intervention techniques used for reproduction mechanisms

Cell Division
• Cell cycle
  ○ Interphase
  ○ Mitotic phase
• Meiosis
• Chromosome mutations
• Cancer
 	
Human Reproduction
• Reproductive system
  ○ Human reproductive organs
• Hormonal regulation
• Gametogenesis
  ○ Spermatogenesis
  ○ Ovogenesis
• Fertilization
• Fertility
• Contraception
  ○ Hormonal
  ○ Mechanical barrier
  ○ Chemical
 	
Development
• Embryonic development
• Growth
• Stem cells
• Cell differentiation
• Morphogenesis
• Pregnancy
  ○ Embryonic period
  ○ Fetal period
• Apoptosis	

Table 1 – Summary of the Compulsory Concepts for Biology

4.1.2 Techniques

Techniques involve methodical procedures that provide guidelines for the proper application of theoretical knowledge. They fall into two categories: *Graphical Language* and *Experimentation.*

Laboratory activities facilitate the understanding of general concepts covered during complex tasks. In addition to the investigative process, these activities provide adult learners with opportunities to develop independent reasoning skills through the choices they are called upon to make at various stages of the process.

Summary of Techniques
Graphical Language
- Observational drawings
Experimentation
- Use of laboratory material - Use of observational instruments - Preparation of samples

Table 2 – Summary of Techniques

4.2 Cultural References

Cultural references are particularly meaningful when it comes to scientific literacy. They contribute to the enrichment of learning situations by rooting them in social and cultural reality. They may include technical objects, technological systems, procedures, products, scientists, community resources, human activities and events related to the learning content of the courses. A list of cultural references is given for each course in Chapter 6.

Cultural references are part of the subject-specific content for the courses in this program of study. While the use of references is compulsory, the list of examples is provided for illustration purposes only. The established list is not exhaustive.

Chapter 5

Organization of the Courses in the Program

Introduction to the Courses

The subject-specific content is presented in two fifty-hour courses to better meet the needs of adult learners.

The Two Biology Courses

The *Biology* program is composed of two courses, BLG-5070-2 and BLG-5071-2. While there are connections between them and they present different facets of the same reality, the two courses are independent of each other and can be taken in any order.

Course BLG-5070-2 deals with issues and problems related to the molecular function of cells and to genetics, genetic diversity and the genetic process of evolution. In examining problems involving applied genetics, adult learners process information not only to seek answers or solutions but also to make use of their knowledge in biology. There are no compulsory laboratory techniques for this course.

Course BLG-5071-2 deals with issues and problems related to cell division mechanisms and human reproduction, growth and development. In examining problems that deal with reproductive technology or developmental biology, adult learners process data not only to seek answers or solutions but also to make use of their knowledge in biology. This course includes laboratory activities.

The following table presents the content of the courses in the *Biology* program.

Biology Courses		
Title	**Hours/Credits**	**General Concepts**
BLG-5070-2 *Applied genetics*	50 hours 2 credits	• Genetics • Molecular Biology • Evolution • Genetic Engineering
BLG-5071-2 *Reproduction and Development*	50 hours 2 credits	• Cell Division • Human Reproduction • Development • Biotechnology

Table 3 – Biology Courses

Chapter 6

Courses

Organization of Course Information

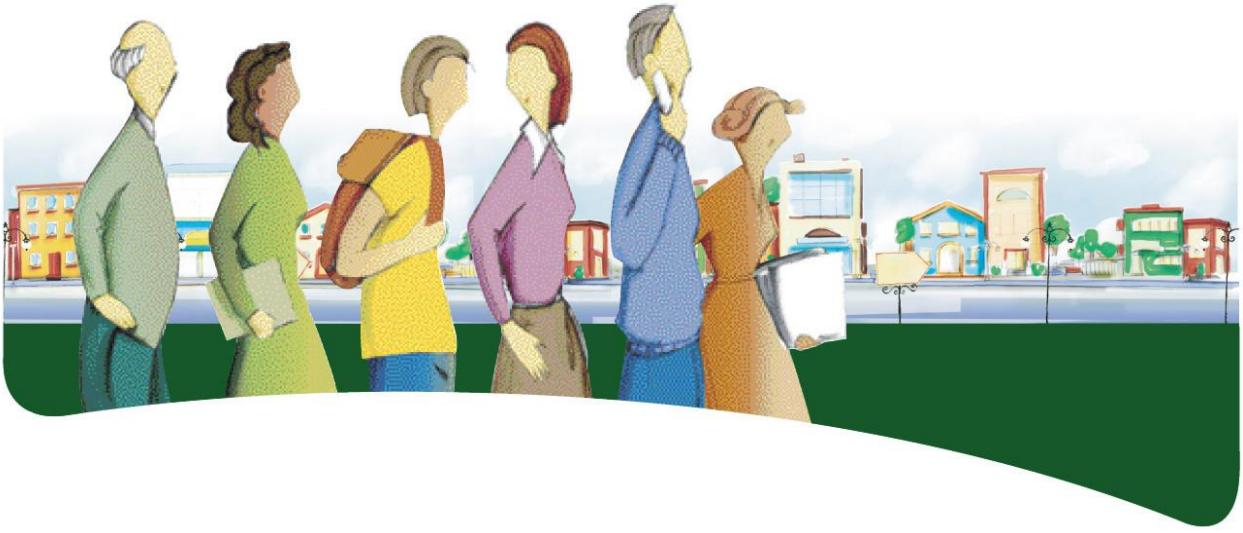
This chapter contains a detailed description of each of the courses in the *Biology* program, presented under the following headings in the order shown below:

Headings
Introduction
Subject-Specific Competencies
Processes
Cross-Curricular Competencies
Subject-Specific Content
Families of Learning Situations
Broad Areas of Learning
Examples of Learning Situations
End-of-Course Outcomes
Evaluation Criteria for Subject-Specific Competencies

BLG-5070-2

Applied Genetics

Biology



BLG-5070-2 Applied Genetics

INTRODUCTION

The course entitled *Applied Genetics* is aimed at enabling adult learners to function effectively in situations from the *Research* and *Expertise* families that involve genetics, its applications and their impact.

In this course, adult learners seek answers to problems related to the molecular function of cells and to genetics, genetic diversity and the genetic process of evolution. They process data to solve problems related to genetic crossing, calculate the probability of hereditary diseases or interpret DNA tests. They apply their knowledge to illustrate the effects of a mutation in a cell's DNA sequence, understand the presence of a genetic disease or explain a species' ability to adapt to a change in its environment. They make informed decisions on social, ethical and environmental issues arising from the use of technologies in molecular biology, particularly gene cloning and transgenesis, and evaluate their impact on society and demographics. Lastly, they use various methods to communicate their ideas and the results of their scientific research on applied genetics.

By the end of this course, in *Research* and *Expertise* situations, adult learners will be able to:

- explain the mechanisms involved in the transmission of hereditary characteristics through genetic crossing based on Mendel's laws or sex-linked inheritance
- interpret information on allelic diversity within a population (e.g. ABO and Rh blood groups)
- interpret a family tree and human karyotypes to answer questions on heredity
- analyze an issue related to a genetic engineering application
- justify the decision of whether or not to produce genetically modified organisms (GMOs) and describe their uses and the risks they pose, taking into account biotechnical, social, ethical and environmental factors
- explain the usefulness of genetic diversity as opposed to the homogeneity of crops and livestock
- discuss ethical issues that may arise from genetic screening for hereditary diseases
- use biotechnical results (for example, to establish a genetic profile or to detect a genetic anomaly during a diagnostic test for hereditary diseases)
- use concrete cases to analyze certain mechanisms of microevolution and their impact on biodiversity or on the survival of a species

SUBJECT-SPECIFIC COMPETENCIES

The following table lists, for each competency, the key features studied in the course. The manifestations of the key features are presented in Appendix 4.

Competency 1 Seeks answers or solutions to problems involving biology	Competency 2 Makes the most of his/her knowledge of biology	Competency 3 Communicates ideas relating to questions involving biology, using the languages associated with science and technology
▪ Defines a problem ▪ Develops a plan of action ▪ Carries out the plan of action ▪ Analyzes his/her results	▪ Puts issues in context ▪ Analyzes a phenomenon or an application from a biological point of view ▪ Explains an issue from the standpoint of biology ▪ Forms an opinion about an issue	▪ Interprets scientific and technological messages ▪ Produces scientific and technological messages

PROCESSES

The investigative processes enable adult learners to examine biological issues, solve problems and study applications. The following are the steps in an investigative process:

- Define the problem
- Formulate a hypothesis
- Test the hypothesis
- Draw conclusions and communicate

The most appropriate investigative processes for this course are modelling, documentary research and the observation method. It is during hypothesis verification that these methods become distinguishable. Section 3.5 and Appendices 2 and 3 present these investigative processes with their respective characteristics.

CROSS-CURRICULAR COMPETENCIES

The cross-curricular competencies supplement the subject-specific competencies. The development of one contributes to the development of the others. Course BLG-5070-2 allows for all the cross-curricular competencies to be put into practice. The sample learning situations presented in this course place particular emphasis on those indicated in grey shading in the table below.

Cross-Curricular Competencies			
Intellectual	**Communication-Related**	**Personal and Social**	**Methodological**
Uses information	Communicates appropriately	Achieves his/her potential	Adopts effective work methods
Solves problems		Cooperates with others	Uses information and communications technologies
Exercises critical judgment			
Uses creativity			

SUBJECT-SPECIFIC CONTENT

A) KNOWLEDGE

The compulsory concepts represent the specific knowledge to be acquired in this course. They are presented in the tables in the following section.

1. Concepts

The knowledge written in italics have been acquired in the Science and Technology programs of the Québec Education Program and must be mobilized again in this course.

<table>
<tr><th colspan="2">The Living World</th></tr>
<tr><td colspan="2">General concept: Genetics</td></tr>
<tr><td colspan="2">Genetics is the study of the hereditary transmission of traits and genetic variation among individuals. Genes, the basic units of inheritance, are found at specific locations on chromosomes. Each gene in a eukaryotic cell has two alleles that undergo segregation and independent assortment during gamete formation.

In applying Mendel’s laws of inheritance, it is necessary to take into account an individual’s phenotype in order to determine the underlying genotype. The Punnett square is used to predict the outcome of controlled crosses. Lastly, the family tree represents unions and descendants over many generations for a given trait, and makes it possible to predict the risk of transmitting a hereditary disease.

For autosomal dominant diseases such as Huntington’s disease to manifest, only a single copy of the mutated gene is required. However, autosomal recessive diseases, such as cystic fibrosis, sickle cell anemia, β-thalassemia, lactic acidosis and phenylketonuria, only develop in homozygous individuals. Heterozygous individuals, who have only one mutated gene, will generally not be affected by these diseases. They are called “healthy carriers.” Sex-based anomalies (e.g. colour blindness, hemophilia, Duchenne muscular dystrophy) are more common in males than in females.</td></tr>
<tr><td>COMPULSORY CONCEPTS</td><td>PREVIOUSLY ACQUIRED KNOWLEDGE</td></tr>
<tr><td>Blood group compatibility</td><td>Determines the compatibility or incompatibility of blood groups (e.g. blood group A individuals can only receive blood from individuals with blood type O or A)</td></tr>
<tr><td>COMPULSORY CONCEPTS</td><td>KNOWLEDGE TO BE ACQUIRED</td></tr>
<tr><td>Heredity</td><td>Defines heredity as the transmission of traits from one generation to the next</td></tr>
<tr><td rowspan="3">Chromosomes</td><td>Describes the role of chromosomes as carriers of genetic information responsible for transmitting hereditary information</td></tr>
<tr><td>Uses a karyotype to distinguish sex chromosomes from autosomes</td></tr>
<tr><td>Establishes the relationship between sex chromosomes and gender determination in humans</td></tr>
<tr><td>Alleles</td><td>Defines an allele as one of the possible forms of a gene</td></tr>
<tr><td>Characteristics</td><td>Recognizes hereditary characteristics in an individual or population (e.g. eye colour, blood group, hereditary diseases)</td></tr>
</table>

Genetics (continued)	
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Homozygous and heterozygous	Defines an individual who is homozygous for a gene as being a carrier of two identical alleles of the gene
	Defines an individual who is heterozygous for a gene as being a carrier of two different alleles of the gene
Dominance and recessiveness	Describes the phenomena of genetic dominance and recessiveness
Genotypes and phenotypes	For a given hereditary characteristic, associates the genotype with the combination of two alleles of the corresponding gene
	Associates the phenotype with observable characteristics of an individual
	Distinguishes the genotype and phenotype of an individual for one or more characteristics using the Punnett square (diagram illustrating crosses) or a karyotype
Mendel's law o Law of dominance o Law of segregation o Law of independent assortment	Describes the main mechanisms of heredity proposed by Mendel and highlights their importance for understanding heredity: law of dominance, law of segregation and law of independent assortment
	Illustrates how independent assortment increases genetic variation due to the existence of many potential chromosome combinations during gamete formation
Genetic Crosses o Autosomal inheritance o Sex-linked inheritance	Determines the proportions of monohybrid or dihybrid crossing outcomes using the rules of probability or the Punnett square
	Uses a family tree to identify the mode of transmission of a hereditary characteristic (autosomal dominant, autosomal recessive or sex-linked)
Hereditary diseases	Uses a family tree to determine the probability of a couple having a child with a hereditary disease (e.g. Huntington's disease, cystic fibrosis, sickle cell anemia, phenylketonuria, colour blindness, hemophilia or Duchenne muscular dystrophy)
	Uses a karyotype to determine whether an individual has or is a carrier of a hereditary disease

General concept: Molecular biology

Molecular biology studies processes such as replication, transcription and translation of DNA, the carrier of genetic information.

The semiconservative model of DNA replication is a highly accurate mechanism involving the pairing of the nitrogenous bases in the nucleotides. It is the process by which DNA is copied. If errors occur during the replication process, the damaged strands are repaired by enzymes.

The transcription of DNA into RNA involves its translation into proteins. In the cell nucleus, DNA is first transcribed into messenger RNA (mRNA). Translation to an amino acid chain then takes place on a ribosome in the cytoplasm using transfer RNA (tRNA). The genetic code specifies the correlation between each mRNA codon and its translation into an amino acid. The same gene can produce different proteins. However, most human DNA is noncoding.

The integrity of the DNA molecules and of the replication, transcription and translation processes ensures the health of an organism, since even a minute change in the nucleotide sequence can lead to the production of an altered protein, have negative physiological effects or produce a lasting change in the phenotype. Mutations are changes in the DNA sequence of a cell.

Many mutations are naturally occurring; they are called spontaneous mutations. Others can be caused by mutagenic agents, such as radiation, chemicals, or viral, bacterial or parasitic infections. Some genetic mutations can cause hereditary diseases or create new alleles. They also contribute to genetic diversity, which is essential for evolution.

COMPULSORY CONCEPTS	**PREVIOUSLY ACQUIRED KNOWLEDGE**
DNA	*Describes the structure of DNA (double helix)*
	Explains the role of DNA (molecule carrying the genetic code of an individual. This information can be found in every cell of the human body)
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Genome	Defines the genome as the complete set of genetic material or as all the DNA molecules of a cell
DNA replication	Associates DNA replication with the process by which genes are duplicated and passed on to two daughter cells
Gene	Defines a gene as a DNA segment that carries the code needed for the synthesis of one or more proteins
	Describes the composition (nitrogenous bases, sugar and phosphate) and the general structure (base pairing in a double helix) of a DNA molecule
Protein synthesis o Transcription o Translation	Associates protein synthesis with the transcription of a DNA strand into mRNA followed by its translation into an amino acid sequence using tRNA
Genetic code	Uses a standard genetic code table to determine the amino acids that correspond to a codon or the coding DNA sequence for a given polypeptide sequence
Mutation	Recognizes the substitutions and the insertions or deletions of base pairs as the two main categories of point mutations occurring during DNA replication
	Identifies a few causes of mutations: errors during genetic replication, repair or recombination and exposure to mutagenic agents (e.g. radiation, chemical products or infections)
	Explains how a mutation can lead to the creation of a different protein or the absence of a protein and influence the onset of a disease or cancer

General concept: Evolution

Evolution is a process of adaptation involving the transformation of organisms over the course of the Earth's history, from the origin of life to the diversity we see today. It explains both the diversity and unity of life. Evolution can occur in response to anything that causes a change in the genetic composition of a population. On a smaller scale, it involves changes in allele frequency in a population over successive generations.

Mechanisms that promote genetic variation have variable consequences for the survival of individuals and species: they can be beneficial, harmful or neutral and, in some cases, lead to speciation. The crossbreeding of plants and animals can lead to the emergence of useful characteristics in the majority of individuals of the same species. This method, known as "artificial selection," is widely used in agronomy. It generates evolutionary changes at a much faster pace than that of the natural selection process. For example, the use of antibiotics increases the frequency of resistant bacteria arising from natural selection. In the same way, the use of chemical substances to fight insect pests promotes the emergence of resistant insects.

Interventions modifying the genetics of a species, combined with the many actions that transform the environment of living organisms, create challenges and problems for the maintenance of biodiversity. The appearance of new species or, conversely, the extinction of certain species, are issues that must be addressed by society.

COMPULSORY CONCEPTS	**PREVIOUSLY ACQUIRED KNOWLEDGE**
Genetic diversity	*Associates genetic diversity with sexual reproduction (the combination of genes from the mother and father ensures diversity)*
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Biological evolution	Describes biological evolution as an observable process by which the hereditary characteristics of organisms change, from one generation to the next, as a result of mechanisms that promote genetic variation
Genetic diversity	Defines genetic diversity as the variability of genes within the same species
	Recognizes the impact of human activity on the distribution of living organisms and on biodiversity (e.g. there is greater genetic diversity in wild species than there is in domesticated species that have undergone artificial selection)
Gene pool	Defines a gene pool as all of the genetic information of a population at a given time
Mechanisms of microevolution o Natural or artificial selection o Gene flow o Genetic drift o Random mating o Mutation	Describes how selection (natural or artificial), gene flow, genetic drift (founder effect, bottleneck effect), random mating and mutations affect the gene pool of a population, from one generation to the next (e.g. high frequency of hereditary diseases in the population of Saguenay–Lac-Saint-Jean)
Adaptation	Illustrates how a population adapts to its environment by increasing the frequency of resistant forms through natural selection (e.g. antibiotic-resistant bacteria or an insect population with decreased sensitivity to an insecticide)
Interventions modifying the genetics of a species	Describes the effects of genetic techniques on the biodiversity of a species (e.g. seed selection, hybridization or cellular cloning)

<table>
<tr><th colspan="2">The Technological World</th></tr>
<tr><td colspan="2">General concept: Genetic engineering</td></tr>
<tr><td colspan="2">Almost all living organisms, whether animals, plants or bacteria, use the same genetic code: one codon codes for one amino acid. The universal nature of the genetic code makes it possible to manipulate genes and transpose them from one organism to another.

The techniques used in molecular biology to sequence, recombine, transfer and analyze genes of living organisms come under genetic engineering. Through gene insertion or modification, genetic engineering makes it possible for plants and animals to lose or acquire traits in just one generation.

The field of genetic engineering is growing at a rapid pace, and new techniques are constantly being developed. For instance, the genetic profile of an individual can be determined by analyzing specific DNA sequences that are unique to each individual. Applications in genetic engineering are used in a variety of fields, including agriculture, medicine and criminology; they tend to transform society and may even transform the human species itself.

These new techniques and their applications raise many social, ethical and environmental issues that society must address.</td></tr>
<tr><th>COMPULSORY CONCEPTS</th><th>PREVIOUSLY ACQUIRED KNOWLEDGE</th></tr>
<tr><td>Genetic transformation
○ Genetically modified organisms (GMOs)</td><td>Names the main advantages and disadvantages of genetic transformations (cancer treatments, pest-resistant and herbicide-tolerant plants, vitamin enrichment or changes in the nature of certain foods, regulations and controls)</td></tr>
<tr><th>COMPULSORY CONCEPTS</th><th>KNOWLEDGE TO BE ACQUIRED</th></tr>
<tr><td>Gene manipulation tools</td><td>Describes the main tools used to manipulate genes (e.g. a restriction enzyme cuts specific base pair sequences on both DNA strands; a cloning vector—a small piece of DNA into which a foreign DNA fragment can be inserted—is capable of autonomous replication in a host cell; recombinant DNA is used to produce therapeutic proteins)</td></tr>
<tr><td>DNA sequencing</td><td>Identifies a moral, ethical or social issue associated with genetic profiling (e.g. eugenics following screening for a hereditary disease, gene patenting or the disclosure of personal information)</td></tr>
<tr><td rowspan="4">Genetic engineering applications
○ Cloning
○ Transgenesis</td><td>Defines cloning as a process used to make identical copies of genes, cells or entire organisms</td></tr>
<tr><td>Recognizes the usefulness of genetic cloning (e.g. the production of vaccines insulin, EPO, somatotropin for dairy production, growth hormone)</td></tr>
<tr><td>Defines transgenesis as the means used to produce a GMO through the transfer of one or more foreign genes into a cell in order to modify its genome</td></tr>
<tr><td>Identifies an issue associated with applied genetic engineering (e.g. the impact of GMO production on biodiversity, the adoption of laws prohibiting human cloning, the use of gene therapy to treat genetic diseases)</td></tr>
</table>

B) CULTURAL REFERENCES

Cultural references make learning situations more meaningful. The following table presents some of the references related to this course. It is neither exhaustive nor compulsory.

<table>
<tr><th colspan="5">CULTURAL REFERENCES</th></tr>
<tr><td colspan="2">Technical objects, technological systems, processes and products</td><td colspan="3">Genetics
- Genetic testing (hereditary diseases)
Molecular biology
- DNA database (CODIS index)
- DNA samples (genetic profile)
Evolution
- Antibiogram
- Genomic selection (dairy cows)
Genetic Engineering
- Agronomy: production of transgenic crops (corn, soy)
- Glofish® (genetically modified zebrafish)
- Harvard OncoMouse
- Production of human insulin by microorganisms
- Golden rice</td></tr>
<tr><th>Area</th><th>Scientists</th><th>Community Resources</th><th>Applications</th><th>Events</th></tr>
<tr><td>The Living World</td><td>Charles Darwin
Frederick Griffith
Barbara McClintock
Gregor Mendel
Thomas Hunt Morgan
Reginald Punnett</td><td>Association de l’acidose lactique du Saguenay–Lac-St-Jean
National DNA Data Bank
Genetic Databases
Corporation de recherche et d’action sur les maladies héréditaires (CORAMH)
Génome Québec
Canadian Animal Genetic Resources
BALSAC database
Svalbard Global Seed Vault</td><td></td><td>Discovery of DNA double helix
Human Genome Project</td></tr>
<tr><td>The Technological World</td><td>Stanley Cohen and Herbert Boyer
Alec Jeffreys
Kary Mullis
Michael Smith
James Watson and Francis Crick</td><td>Association de thérapie génique du Québec
Commission de l’éthique en science et en technologie du Québec
Armand-Frappier Museum
www.ogm.gouv.qc.ca (information on GMOs)
Network of Applied Genetic Medicine</td><td>DNA Identification Act (S.C. 1998, c. 37)
Monsanto Protection Act</td><td>Cloning of Starbuck
Cartagena Protocol</td></tr>
</table>

FAMILIES OF LEARNING SITUATIONS

The learning situations in this course, derived from the *Research* and *Expertise* families, involve genetic applications and their impact on society and biodiversity. These situations cover various general concepts. The following paragraphs contain examples of tasks that could be assigned to adult learners in learning situations involving one or more general concepts.

A situation involving general concepts in molecular biology and genetic engineering might require adult learners to determine an individual's genetic profile. Adult learners could identify and describe genetic engineering techniques used to manipulate genetic information. In the case of a mutation, they would be able to demonstrate that a change in a specific DNA or RNA sequence can lead to changes in gene expression.

A situation involving molecular biology might require adult learners to reflect on the origin of a genetic disease and ask questions about the expression of genetic information, such as the relationship between DNA and protein synthesis. Making adult learners aware of the consequences of exposure to mutagenic agents enables them to assess the effects of such agents. The study of genetics can help them understand that not all genetic diseases are necessarily hereditary.

In a learning situation involving the general concepts of evolution and genetics, adult learners might process qualitative and quantitative data that reflect a change in the genetic makeup of a population over time. Using the different mechanisms of evolution, they could explain these changes or make predictions about the gene pool of a population. The study of the general concept of molecular biology would enable them to use data to make connections between DNA sequences and different traits observed in individuals.

A situation involving genetics might require adult learners to solve a problem related to heredity. Using a karyotype model, they could model the processes that ensure the transmission of genetic information. They could describe the genotype and phenotype for a specific allele or identify the maternal or paternal origin of a chromosome. They would apply their knowledge to explain how parents transmit some of their traits to their children. Adult learners could use the general concept of genetic engineering to explain how DNA is analyzed and how this permits defective genes to be identified.

In a learning situation involving the general concept of genetic engineering, adult learners might justify their opinion of a genetic engineering technique, such as genetic cloning or transgenesis. They could describe certain genetic manipulations and recognize their therapeutic applications. Using the general concept of evolution, adult learners could explain how interventions that modify the genetics of a species may have an impact on the maintenance of biodiversity.

BROAD AREAS OF LEARNING

Learning situations will have more meaning for adult learners if they are related to the broad areas of learning. The broad areas of learning that are most readily applicable to the learning situations for the course BLG-5070-2 are *Health and Well-Being*, *Environmental Awareness and Consumer Rights and*

Responsibilities, *Media Literacy* and *Citizenship and Community Life*. The examples following the presentation of the families of learning situations for this course reflect the educational aim of the broad areas of learning *Environmental Awareness and Consumer Rights and Responsibilities*, *Media Literacy* and *Citizenship and Community Life*.

Broad Areas of Learning
Health and Well-Being
Career Planning and Entrepreneurship
Environmental Awareness and Consumer Rights and Responsibilities
Media Literacy
Citizenship and Community Life

EXAMPLES OF LEARNING SITUATIONS

In the following examples of learning situations, the main tasks to be carried out help adult learners develop of the three subject-specific competencies. They fall under the *Research* and *Expertise* families.

Research Family: Looking for the Guilty Party

A few strands of hair were found at a crime scene. Police suspect two individuals and have asked you to compare the DNA collected at the crime scene with the DNA of the suspects. At the lab, they have determined the genetic profile of the DNA found at the crime scene, and the technician hands you the results of the gel electrophoresis. You have discovered the suspects' genetic profiles in their files. You must identify the guilty party.

To support your decision, your file must include:

- a presentation of the problem supported by a description of the DNA structure and its replication
- an explanation of the scientific principles used to determine an individual's genetic profile
- a DNA analysis of the suspects using restriction enzymes
- a comparison of the results of the gel electrophoresis with the analysis of the suspects' genetic profiles

Expertise Family: Transgenic plants

Joe Green's family has been growing corn for several generations and recently set aside part of their farmland for growing soybeans. However, the significant changes in precipitation and temperature of the last few years are forcing this Québec business to review its agricultural practices. Its corn crops are frequently attacked by pests, and its soybean crops are overrun with weeds.

Since the last general meeting of grain producers, Joe Green has been looking into new transgenic seeds: Bt corn seeds are pest resistant and transgenic soybeans are herbicide resistant. Would it be a good idea for Joe Green to use GMOs? Why? What are the advantages and the risks?

In your justification, be sure to provide:

- a description of what a GMO is and an explanation of the genetic code and protein synthesis
- information on transmission mechanisms for hereditary traits
- the factors that influence evolution mechanisms and the social and environmental repercussions of artificial selection following the use of GMOs
- a justification of the advantages and disadvantages of using GMOs in agriculture

END-OF-COURSE OUTCOMES

Learning situations are administered on the premise that the adult learner will become familiar with an investigative process involving the experimental method, modelling, documentary research and the observation method. In biology, these learning situations enable adult learners to apply their problem-solving skills and knowledge, and to produce messages.

Adult learners solving a problem related to genetics, its applications and their impact develop a representation of the problem based on their reading and interpretation of scientific messages. They develop an experimental protocol or a model based on one of their hypotheses, applying their knowledge of genetics, molecular biology, evolution and genetic engineering. They plan the steps of their research and select those available resources that will enable them to find answers to the questions raised. They implement a plan of action by carrying out selected activities or describe a plan of action whose activities have already been completed. In the laboratory, they demonstrate their ability to prepare and observe samples. When necessary, they use a modelling approach to solve the problem. Adult learners may also use data collections to find solutions to genetic problems. For example, they may use their understanding of genetic replication, transcription and translation to analyze data collected from a DNA test. They use concepts or laws to explain the results of genetic crosses, which they illustrate with appropriate models while applying the writing conventions for genetics. If necessary, they make corrections to the planned steps using the appropriate techniques. In a summary report, they use the results obtained, sometimes presenting the information in charts or graphs. They provide explanations that take the results into account, and check whether the hypothesis is consistent with the analysis of the results. They recognize the relationship between solving scientific problems and the development of biotechnologies.

Adult learners who study an issue or technological application involving genetics or molecular biology formulate questions related to social, ethical or environmental issues. They identify the characteristics of the issue or application in order to understand the underlying scientific principles. They explain the importance of genetic diversity for the evolution of a population and its capacity to adapt to changes in its environment. Lastly, they defend an opinion on issues related to progress in molecular biology and its resulting applications. By relying on their knowledge of genetics, they propose various explanations or solutions that take into account the issue as a whole.

EVALUATION CRITERIA FOR SUBJECT-SPECIFIC COMPETENCIES

Evaluation Criteria for Competency 1	Evaluation Criteria for Competency 2	Evaluation Criteria for Competency 3
▪ Appropriate representation of the situation ▪ Development of a suitable plan of action ▪ Appropriate implementation of the plan of action ▪ Development of relevant explanations, solutions or conclusions	▪ Appropriate interpretation of the issue ▪ Appropriate use of knowledge of biology ▪ Appropriate formulation of explanations or solutions	▪ Accurate interpretation of scientific messages ▪ Appropriate production or transmission of scientific messages

BLG-5071-2

Reproduction and Development

Biology

BLG-5071-2 Reproduction and Development

INTRODUCTION

The course entitled *Reproduction and Development* is aimed at enabling adult learners to function in situations from the *Research* and *Expertise* families that involve reproduction, growth and development as well as related biotechnologies.

In this course, adult learners seek answers to questions about human reproduction, growth and development. They process information to solve problems related to cell division mechanisms, birth control, infertility and the development of the embryo during pregnancy. They apply their knowledge to explain the processes involved in reproduction and development and how these processes are regulated by hormones. They describe intervention techniques used for reproduction mechanisms. They study the incidence of environmental factors on the development of the embryo and fetus and describe the underlying scientific principles in prenatal screening and diagnostic techniques. They make informed decisions on social issues arising from the use of reproductive biotechnology, including medically assisted procreation, reproductive or therapeutic cloning and transgenesis, and evaluate its impact on society and demographics. Lastly, they use various methods to communicate their ideas and the results of their scientific research on the human biological cycle.

By the end of this course, in *Research* and *Expertise* situations, adult learners will be able to:

- identify the cellular processes involved in the reproduction, development and growth of an organism
- interpret information obtained from observing the phases of the cellular cycle of an animal or plant cell, using models and diagrams
- determine, based on specific cases, the consequences of a chromosome mutation during meiosis or mitosis (e.g. trisomy 21 (Down syndrome), cancer)
- explain the scientific principles behind the technologies that employ cell division mechanisms (e.g. stem cell research, cellular implants, therapeutic or reproductive cloning)
- explain how hormonal regulation affects the human reproductive system
- comment on a reproductive technology by referencing its underlying scientific concepts
- discuss the social and ethical issues raised by the use of reproductive technologies (e.g. interventions using medically assisted procreation techniques, prenatal diagnostic testing and decisions regarding pregnancy termination, the necessity of certain tests to monitor fetal development)

SUBJECT-SPECIFIC COMPETENCIES

The following table lists, for each competency, the key features studied in the course. The manifestations of the key features are presented in Appendix 4.

Competency 1 Seeks answers or solutions to problems involving biology	Competency 2 Makes the most of his/her knowledge of biology	Competency 3 Communicates ideas relating to questions involving biology, using the languages associated with science and technology
▪ Defines a problem ▪ Develops a plan of action ▪ Carries out the plan of action ▪ Analyzes his/her results	▪ Puts issues in context ▪ Analyzes a phenomenon or an application from a biological point of view ▪ Explains an issue from the standpoint of biology ▪ Forms an opinion about an issue	▪ Interprets scientific and technological messages ▪ Produces scientific and technological messages

PROCESSES

The investigative processes enable adult learners to solve problems and study applications. The following are the steps in an investigative process:

- Define the problem or need
- Formulate a hypothesis
- Test the hypothesis
- Draw conclusions and communicate

The most appropriate investigative processes for this course are the experimental method, modelling, documentary research and the observation method. It is during hypothesis verification that these methods become distinguishable. Section 3.5 and Appendices 2 and 3 present these investigative processes, with their respective characteristics.

CROSS-CURRICULAR COMPETENCIES

The cross-curricular competencies supplement the subject-specific competencies. The development of one contributes to the development of the others. Course BLG-5071-2 allows for all the cross-curricular competencies to be put into practice. The sample learning situation presented in this course places particular emphasis on those indicated in grey shading in the table below.

Cross-Curricular Competencies			
Intellectual	**Communication-Related**	**Personal and Social**	**Methodological**
Uses information	Communicates appropriately	Achieves his/her potential	Adopts effective work methods
Solves problems		Cooperates with others	Uses information and communications technologies
Exercises critical judgment			
Uses creativity			

SUBJECT-SPECIFIC CONTENT

A) KNOWLEDGE

The compulsory concepts and techniques are presented in the tables in the following two sections.

1. Concepts

The knowledge written in italics have been acquired in the Science and Technology programs of the Québec Education Program and must be mobilized again in this course.

<table>
<tr><th colspan="2">The Living World</th></tr>
<tr><td colspan="2">General concept: Cell division</td></tr>
<tr><td colspan="2">Cell division is the process by which parent cells divide into two or more daughter cells. In eukaryotic cells, there are two types of cell division: mitosis, which occurs in somatic cells, and meiosis, which occurs in germ cells. All cell division is preceded by DNA replication.
Mitosis ensures the development, growth and regeneration of cells and the preservation of their gene pool. It is part of the cellular cycle that includes the interphase and the mitotic phase. A regulatory mechanism governs the phases of the cell cycle, blocking it when an anomaly is detected. Tumour cells do not respond to this mechanism: they divide in an uncontrolled manner and form tumours.
Meiosis occurs in the gonads and generates daughter cells having half the number of chromosomes of the parent cell. The random assortment of chromosomes and genetic recombination following the exchange of fragments between homologous chromosomes increases the genetic diversity of the cells produced.
Chromosomal abnormalities are changes in the number and/or structure of chromosomes resulting from crossing over or nondisjunction errors. Genetic crossing over can result in deletions or duplications. Nondisjunction errors during meiosis can produce gametes with too many chromosomes or, conversely, too few chromosomes (trisomy and monosomy).
Changes in the genome can occur in somatic cells (somatic mutation) and in the gonads (germline mutation). Mutations can be random and spontaneous or caused by environmental factors, such as chemical products, X-rays and certain viruses. Some mutations are “silent” in that they have no effect on the organism, while others lead to cancer or genetic diseases that can be passed down to the organism’s offspring.</td></tr>
<tr><th>COMPULSORY CONCEPTS</th><th>PREVIOUSLY ACQUIRED KNOWLEDGE</th></tr>
<tr><td rowspan="2">Cells
o Cellular components
o Cell membrane
o Nucleus
o Chromosomes, genes</td><td>Identifies the main cellular components visible under a microscope (cell membrane, cytoplasm, nucleus, vacuoles)</td></tr>
<tr><td>Describes the role of the main cellular components visible under a microscope</td></tr>
<tr><td>Mitosis</td><td>Describes the functions of mitosis (reproduction, growth and regeneration)</td></tr>
<tr><td>Functions of cell division</td><td>Distinguishes the functions of mitosis from those of meiosis</td></tr>
<tr><td rowspan="2">Meiosis and the sexual life cycle: meiosis, fertilization</td><td>Describes the function of meiosis (gamete production)</td></tr>
<tr><td>Indicates the advantages of the sexual life cycle (e.g. the mixing of genes from parents, the difference between parents and their offspring)</td></tr>
</table>

COMPULSORY CONCEPTS	KNOWLEDGE TO BE ACQUIRED
Cell cycle o Interphase o Mitotic phase	Describes interphase as a succession of three phases (two growth phases during which protein and RNA synthesis occurs, and a DNA replication phase between the two growth phases)
	Describes the four phases of mitosis: prophase, metaphase, anaphase and telophase
	Explains the importance of maintaining the same number of chromosomes during mitosis to ensure that all the characteristics of a cell's genetic material are preserved
Meiosis	Describes the phases of meiosis I (reduction cycle) and meiosis II (equational division)
	Explains the necessity of reducing the number of chromosomes during spermatogenesis and ovogenesis
	Illustrates how crossing over and independent assortment during meiosis can be a source of genetic diversity among individuals of the same species
	Distinguishes between mitosis and meiosis in terms of their phases, the number of cells produced, the number of chromosomes and the exchange of genetic material
Chromosome mutation	Describes a mutation as an irreversible change in genetic information that may lead to an anomaly in the number or structure of chromosomes
	Distinguishes germline mutations from somatic mutations based on their location and potential consequences (e.g. germline mutations are hereditary; somatic mutations can cause genetic diseases, a cancerization process or simply be silent)
	Identifies on a karyotype an autosomal anomaly (e.g. Down syndrome or trisomy 21; Edward's syndrome or trisomy 18; Patau syndrome or trisomy 13) or a gonosome anomaly (e.g. Turner syndrome [X0], Klinefelter syndrome [XXY], Jacob's syndrome [XYY])
Cancer	Associates cancer with a group of diseases involving tumour cells that do not respond to the normal regulation mechanism of the cell cycle or to the normal function of apoptosis

General concept: Human reproduction	
Sexual reproduction is a form of reproduction in which two parents produce gametes (sex cells) in their gonads that eventually fuse to form a zygote. It is a major source of genetic diversity in populations. In humans, hormones secreted by the hypothalamus, pituitary gland and gonads regulate the functioning of the reproductive system and the production and maturation of gametes. However, certain factors related to lifestyle or external events that generate high levels of stress or strong emotions can disrupt the functioning of the reproductive system and sometimes even stop sexual cycles. Understanding the hormonal mechanisms involved in reproduction makes it possible to control procreation and contraception, and to provide medical assistance in cases of infertility. Some methods of contraception prevent the fusion of gametes by mechanical means (condoms) or chemical means (chemical birth control). Others prevent implantation, either mechanically (IUD) or hormonally (emergency contraceptive pill). Female hormonal contraception prevents ovulation by acting on hormonal regulation mechanisms.	
COMPULSORY CONCEPTS	**PREVIOUSLY ACQUIRED KNOWLEDGE**
Genetic diversity	*Associates genetic diversity with sexual reproduction (the combining of genes from the mother and father ensures diversity)*
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Reproductive system ○ Human reproductive organs	Compares the anatomical and physiological differences between the male and female reproductive systems (structures, functions, cyclical functioning, hormonal regulation)
	Distinguishes the sperm from the ovum in terms of their size, content and structure
	Recognizes the dual function of gonads (ovaries and testicles) as both exocrine, which involves the production of gametes that make fertilization possible, and endocrine, which involves the production of hormones
Hormonal regulation	Defines a hormone as a chemical messenger secreted by a gland and carried by the blood to act on target cells
	Describes the role of gonadoliberin (GnRH) and various other hormones (follicle-stimulating hormone [FSH], luteinizing hormone [LH], estrogen, progesterone, testosterone) in the development of genitalia and the development and maintenance of secondary sexual characteristics in men and women
	Explains the interaction among the main female reproductive hormones (estrogen, progesterone, luteinizing hormone [LH], follicle-stimulating hormone [FSH] and gonadoliberin [GnRH]) in maintaining the menstrual cycle (e.g. ovarian feedback to the hypothalamus and pituitary gland, synchronization of ovarian and uterine cycles)
	Explains the interaction among the main male reproductive hormones (testosterone, luteinizing hormone [LH], follicle-stimulating hormone [FSH] and gonadoliberin [GnRH]) in controlling testicular activity (e.g. constant production of testosterone, testicular feedback to the hypothalamus and pituitary gland)

COMPULSORY CONCEPTS	KNOWLEDGE TO BE ACQUIRED
Gametogenesis o Spermatogenesis o Ovogenesis	Compares the process of gamete formation in men and women in terms of location, rate of spermatogenesis or ovogenesis, production period, and the number and type of gametes produced
Fertilization	Defines fertilization as the process leading to the formation of a zygote
Fertility	Explains causes of declining fertility in women (e.g. anomalies in ovulation, the Fallopian tubes, the cervical mucus; endometriosis) and in men (e.g. oligospermia, azoospermia, asthenospermia)
Contraception o Hormonal o Mechanical barrier o Chemical	Describes the action mechanisms of various methods of contraception (e.g. combination birth control pills suppress the surge of LH and FSH associated with ovulation, thus preventing ovulation; condoms prevent sperm from reaching the ovum)

General concept: Development

The development of multicellular organisms encompasses all the changes undergone from birth to death. This involves not only the embryonic period, but also growth after birth, which involves an increase in the size and number of cells and the regeneration and repair of tissues to ensure the survival of the organism. Development has two objectives: to generate diversified cells and to ensure the sustainability of life from one generation to the next.

All animals go through similar stages of embryonic development: morula, blastula and gastrula. Organs develop in an organized manner from distinct cellular layers (ectoderm, mesoderm and endoderm) known as “germ layers.” Embryonic development includes a process of growth, cellular differentiation and morphogenesis resulting from asymmetric cell division.

Certain teratogens (drugs, viruses, irradiation, etc.) can disrupt the normal development of an embryo or fetus and cause birth defects resulting in structural abnormalities. The medical supervision of pregnancy involves the use of various techniques to closely monitor the process and prevent maternal and fetal pathologies. The voluntary termination of pregnancy may be suggested if a chromosomal or developmental anomaly is detected during fetal karyotyping.

Stem cells have no specialized function and play an important role in cell development. They are present in embryos and in various adult tissues. Through stem cell differentiation, human beings are capable of renewing their cells and repairing damaged tissues.

Apoptosis is a critical process in morphogenesis. This programmed cell death is necessary for the survival of organisms. In cancer cells, the apoptotic process is defective. Conversely, excessive apoptosis leads to degenerative diseases (e.g. Parkinson’s disease, Alzheimer’s disease, AIDS).

COMPULSORY CONCEPTS	PREVIOUSLY ACQUIRED KNOWLEDGE
Tissues	*Defines a tissue as a set of identical or non-identical cells that work together to perform a common function in an organism*
Organs	*Defines an organ as a differentiated part of an organism that is composed of tissues and that performs one or more specific functions*
Systems	*Defines a biological system as a set of cells, tissues or organs that perform one or more common functions*
	Describes the main functions performed by the human body (nutrition, relationships, reproduction)

COMPULSORY CONCEPTS	KNOWLEDGE TO BE ACQUIRED
Embryonic development	Describes the main physiological phenomena that take place during the stages of embryonic and fetal development starting with the formation of the zygote: cleavage (formation of the morula), blastulation, gastrulation (formation of germ layers) and organogenesis
Growth	Recognizes the role of growth hormone (GH) in stimulating bone and cartilage growth
Stem cells	Defines stem cells as undifferentiated cells that have the ability to renew themselves, divide indefinitely and produce differentiated cells
Cell differentiation	Recognizes cell differentiation as the development of various types of cells from a stem cell following asymmetric cell division
Morphogenesis	Defines morphogenesis as the process through which organs and tissues take their shape in an ordered, organized manner
Pregnancy o Embryonic period o Fetal period	Associates certain metabolic and physiological changes during pregnancy with the release of various hormones: progesterone, estrogen, human chorionic gonadotropin (HCG), and oxytocin
	Describes the underlying principle of pregnancy tests: detection of human chorionic gonadotropin (HCG) produced by the embryo or placenta
	Explains why, during pregnancy, certain factors pose a risk to the normal development of the embryo or fetus, potentially leading to birth defects (e.g. phocomelia or ectromelia caused by thalidomide; heart defects or vision and auditory problems caused by rubella)
Apoptosis	Recognizes programmed cell death (apoptosis) as a critical process in the formation and maintenance of many tissues

<table>
<tr><th colspan="2">The Technological World</th></tr>
<tr><td colspan="2">General concept: Biotechnology</td></tr>
<tr><td colspan="2">The development of many technologies, particularly for research into cell growth, stem cells, cloning and the treatment of certain diseases such as cancer or spinal injuries, is the result of scientific knowledge of the mechanisms involved in cell division, reproduction and development. The use of technical interventions on reproductive mechanisms has given rise to medical acts once deemed unthinkable, raising a series of ethical issues that society must address.

In human beings, assisted procreation is used to solve certain infertility problems. Treatments involve techniques that reproduce in the laboratory part of the natural processes of fertilization and embryonic development. These rapidly growing practices give rise to many ethical and social issues. The donation and freezing of embryos and gametes, surrogacy and preimplantation diagnosis are examples of topics that are causes for concern.

Prenatal genetic testing is used to screen for genetic anomalies in the fetus. Some tests are non-invasive (ultrasounds), while others are invasive (amniocentesis and chorionic villus sampling). Embryonic cells harvested during these tests can be used to establish their karyotype. The possibility of diagnosing problems before a child is born means having the option of terminating a pregnancy or anticipating treatments if the fetus is found to be abnormal. This raises a bioethical issue of what exactly is considered to be “normal.”</td></tr>
<tr><td>COMPULSORY CONCEPTS</td><td>PREVIOUSLY ACQUIRED KNOWLEDGE</td></tr>
<tr><td>Cell cultures</td><td>Names parameters to be controlled in the case of cultured cells (sources of parent cells, growth, behaviour, preservation, characteristics of culture media, physicochemical parameters, ethical standards)</td></tr>
<tr><td>COMPULSORY CONCEPTS</td><td>KNOWLEDGE TO BE ACQUIRED</td></tr>
<tr><td rowspan="2">Prenatal diagnosis
o DNA screening tests
o Diagnostic tests</td><td>Distinguishes screening tests (which indicate the likelihood of a fetus having a chromosomal anomaly) from prenatal diagnostic tests (which determine the condition of the fetus before birth)</td></tr>
<tr><td>Analyzes prenatal screening and diagnostic techniques (e.g. blood sampling from the mother, ultrasound, amniocentesis, chorionic villus sampling)</td></tr>
<tr><td>Medically assisted procreation</td><td>Describes the physiological and mechanical basis of various medically assisted procreation techniques, such as artificial insemination, embryo transfer, in vitro fertilization (ovarian stimulation, egg retrieval, intracytoplasmic injection)</td></tr>
<tr><td>Intervention techniques used for reproduction mechanisms</td><td>Discusses an issue related to an intervention technique used on reproduction mechanisms (e.g. sterilization reversal, egg donations, freezing of extra embryos, embryo cloning, eugenics, embryo sexing, selective breeding of cattle)</td></tr>
</table>

2. Techniques

The techniques presented here fall into two categories: *Graphical Language* and *Experimentation*. Some of these techniques require the use of instruments, tools or chemicals. Those using such techniques must be constantly vigilant about safety and the use of safety equipment in the laboratory.

IN THE LABORATORY	
TECHNIQUES	**KNOWLEDGE TO BE ACQUIRED**
Graphical Language	
- Observational drawings	• Represents all the elements that characterize the object under observation • Ensures a realistic representation when making an observational drawing • Includes in the observational drawing all the information needed for its interpretation (magnification, legend, title)
Experimentation	
- Use of laboratory materials	• Uses laboratory materials safely (e.g. when cutting with a scalpel, placing a cover slip on a slide, grinding with a glass rod, chopping with a blade) • Handles laboratory materials appropriately (e.g. when using a dropper to collect a product)
- Use of observational instruments	• Uses observational instruments (e.g. microscope, binocular, magnifying glass) appropriately
- Preparation of samples	• Carries out operations necessary to observe and analyze a sample (e.g. uses sterile tweezers, washes work area with disinfectant, prepares a microscope slide, adds a colouring agent)

B) CULTURAL REFERENCES

Cultural references make learning situations more meaningful. The following table presents some of the references related to this course. It is neither exhaustive nor compulsory.

CULTURAL REFERENCES	
Technical objects, technological systems, processes and products	Cell Division - Microscope Human Reproduction - Birth control pill - Emergency contraceptive pill - Fertility test Development - Pregnancy test - Bone marrow transplant Biotechnology - Ultrasound - Microinjection - Sperm banks

Area	Scientists	Community Resources	Applications	Events
The Living World	Walther Flemming Gregory Pincus and John Rock Édouard Van Beneden Karl Ernst von Baer	Thalidomide Victims Association of Canada Association québécoise des personnes de petite taille Canadian Cancer Society Birthing centres		Rise to fame of Siamese twins Chang and Eng Bunker (conjoined twins) Marketing of the birth control pill Discovery of Down syndrome Story of the Dionne quintuplets
The Technological World	Robert Edwards	Commission de l'éthique en science et en technologie du Québec Prenatal Screening Program of Québec Assisted Procreation Services	Assisted Human Reproduction Act (S.C. 2004, c.2)	Birth of Dolly the sheep Birth of Louise Brown (conceived by *in vitro* fertilization - IVF)

FAMILIES OF LEARNING SITUATIONS

The learning situations in this course, derived from the *Research* and *Expertise* families, deal with the processes associated with human reproduction, development and growth and their regulation by hormones. These situations cover various general concepts. The following paragraphs contain examples of tasks that could be assigned to adult learners in learning situations involving various combinations of general concepts.

In a situation involving the general concepts of human reproduction and biotechnology, adult learners could be required to demonstrate how an understanding of hormone regulation makes it possible to develop methods that provide a certain amount of control over human reproduction. They could explain infertility treatments by comparing them to natural conception and highlight the issues raised by medically assisted procreation for society and couples.

In a learning situation on pregnancy, adult learners could apply their knowledge of human development and make connections with human reproduction. For instance, they could analyze data from fictitious pregnancy tests, establish the chronological steps of embryogenesis or discuss the effects of substance abuse on fetal development. Their study of the general concept of biotechnology could permit them to evaluate the necessity of using diagnostic tests to monitor fetal development.

In a learning situation involving cell division, adult learners could compare the cycle of a healthy cell with that of a cancer cell and discuss cell regulation, growth, division and death. They could apply their knowledge of the general concept of human reproduction to describe the consequences of cancer treatments, such as chemotherapy, on cell division and gametogenesis. Once they have acquired an understanding of the notions related to the concept of development, they could explain replacing damaged cells with stem cells as a way of treating many diseases.

In a learning situation dealing with the concepts of development and biotechnology, adult learners could describe how cloning may be useful for research into embryonic development or cell differentiation and its dysfunction. They could then show why certain applications may actually pave the way for solutions to many health problems.

BROAD AREAS OF LEARNING

Learning situations will have more meaning for adult learners if they are related to the broad areas of learning. The broad areas of learning most readily applicable to the learning situations for the course BLG-5071-2 are *Health and Well-Being*, *Environmental Awareness and Consumer Rights and Responsibilities*, *Media Literacy* and *Citizenship and Community Life*. The examples following the presentation of the families of learning situations for this course reflect the educational aim of the broad areas of learning *Environmental Awareness and Consumer Rights and Responsibilities*, *Media Literacy* and *Citizenship and Community Life*.

Broad Areas of Learning
Health and Well-Being
Career Planning and Entrepreneurship
Environmental Awareness and Consumer Rights and Responsibilities
Media Literacy
Citizenship and Community Life

EXAMPLES OF LEARNING SITUATIONS

In the following examples of learning situations, the main tasks to be carried out help adult learners develop the three subject-specific competencies. They fall under the *Research* and *Expertise* families.

Research **Family: A Baby at Last**

Couples may experience infertility for a variety of reasons. Fortunately, there are many techniques available to help infertile couples fulfil their desire to have a child.

You are a member of the medically assisted procreation team at your hospital. You have just received the results of the tests Ms. X and Mr. Y have undergone to determine what may be causing their infertility. You read and analyze the results before presenting them to the patients' doctor, who will then be able to propose a solution adapted to their situation.

Your file must include:

- a representation of the problem, including a description of the structure of human reproductive organs and an explanation of gamete formation and of the neuroendocrine regulation of reproductive systems
- a hypothesis regarding the causes of the couple's infertility
- an analysis of Mr. Y's spermogram and sperm and Ms. X's hormone levels (LH, FSH and progesterone)
- a functional comparison of Mr. Y and Ms. X's reproductive organs and those of a fertile couple
- a description of some medically assisted procreation techniques
- a suggested solution for couple XY

***Expertise* Family: Decision Time**

At last! After several unsuccessful attempts, your big sister is finally pregnant. She was closely monitored by her doctor and underwent several tests, including a screening test for Down syndrome (trisomy-21). The test results indicate a high likelihood of her having a child with Down syndrome. She must now decide whether or not to undergo a diagnostic test (an amniocentesis to analyze the baby's chromosomes).

Your sister comes to you for advice. To help her decide, you need to explore the issues with her.

The information you provide must include:

- a description of Down syndrome with an example of a karyotype illustrating this chromosomal anomaly
- an illustration of the different phases of meiosis with an explanation of the process and of the importance of meiotic reduction in chromosome number during ovogenesis
- a description of a few of the developmental characteristics of children with Down syndrome
- an argument concerning the ethical issues raised by certain prenatal diagnostic tests

END-OF-COURSE OUTCOMES

Learning situations are administered on the premise that adult learners will become familiar with an investigative process involving the experimental method, modelling, documentary research and the observation method. In biology, these learning situations enable adult learners to apply their problem-solving skills and knowledge, and to produce messages.

Adult learners solving a problem related to reproduction and development develop a representation of the problem based on their reading and interpretation of scientific messages. They develop an experimental protocol or a model based on one of their hypotheses, applying their knowledge of cell division, human reproduction and development. They plan the steps of their research and select those available resources that will enable them to find answers to the questions raised. They implement a

plan of action by carrying out the planned activities. In the laboratory, they demonstrate their ability to prepare and observe samples. They use different instruments and produce observational drawings when necessary. Adult learners may also use data collections to find solutions to problems related to development. If necessary, they make corrections to the planned steps using the appropriate techniques. In a summary report, they use the results obtained, sometimes presenting the information in charts or graphs. They provide explanations that take the results into account and check whether the hypothesis is consistent with the analysis of the results. They recognize the relationship between solving scientific problems and the development of biotechnologies.

Adult learners who study an issue or technological application involving reproduction and development formulate questions related to social, ethical or environmental issues. They identify the characteristics of the issue or application in order to understand the underlying scientific principles. For example, they analyze various reproductive technologies by applying their knowledge of the reproductive system and embryonic development. Using concepts or models, they explain an issue related to prenatal diagnosis, illustrate processes associated with human development and refer to related hormonal mechanisms. By applying their knowledge of cell division, they explain how a cell division anomaly can lead to a chromosomal mutation or cancer. Lastly, they defend an opinion on issues related to intervention techniques used for reproduction mechanisms and their ethical and social repercussions. By relying on their knowledge of reproduction and development, they suggest various explanations or solutions that take into account the issue as a whole.

EVALUATION CRITERIA FOR SUBJECT-SPECIFIC COMPETENCIES

Evaluation Criteria for Competency 1	Evaluation Criteria for Competency 2	Evaluation Criteria for Competency 3
▪ Appropriate representation of the situation ▪ Development of a suitable plan of action ▪ Appropriate implementation of the plan of action ▪ Development of relevant explanations, solutions or conclusions	▪ Appropriate interpretation of the issue ▪ Appropriate use of knowledge of biology ▪ Appropriate formulation of explanations or solutions	▪ Accurate interpretation of scientific messages ▪ Appropriate production or transmission of scientific messages

Appendices

Appendix 1

Exploration and analytical strategies enable the adult learner to progress more effectively towards an answer or solution when using an investigative process.

Exploration Strategies
• Collecting as much scientific, technological and contextual information as possible to define a problem or predict patterns • Referring to similar problems that have already been solved • Generalizing based on several distinct cases that are structurally similar • Anticipating the results of a process • Developing various scenarios • Exploring various possible solutions • Considering various points of view on scientific issues

Analytical Strategies
• Determining the constraints and important elements involved in solving a problem • Dividing a complex problem into simpler subproblems • Using different types of reasoning (e.g. inference, inductive and deductive reasoning, comparison, classification, prioritization) in order to process information • Reasoning by analogy in order to process information and adapt knowledge related to biology • Selecting relevant criteria to help determine where one stands on an issue related to biology

Appendix 2

The following table illustrates the tasks accomplished at each step of the investigative process.

Investigative Processes	
Steps	Examples
Define the problem	Identify the relevant information. Find the related concepts. Use personal theoretical knowledge, theoretical knowledge drawn from documents, previous experiments, past experience or logic.
Formulate a hypothesis	Develop questions based on different facts. Make analogies or try to predict results. Establish causal relationships. Propose a model.
Test the hypothesis	Prepare and make observations. Conduct an experiment. Build a model or do documentary research to prove or disprove the initial hypothesis.
Draw conclusions	Express understanding of the facts. Develop an explanation or a new model or theory.
Communicate	Formulate an answer, solution, explanation, model or opinion.

Appendix 3

Scientific Methods for Testing a Hypothesis

Experimental Method	
The experimental method involves the development of an experimental procedure that includes the identification of a certain number of variables. The aim of the procedure is to identify and compare observable or quantifiable elements and check them against the initial hypotheses. Moving back and forth between the different stages of the experimental method allows adult learners to raise new questions, formulate new hypotheses, adjust the experimental procedure and take the limitations of the experiment into account.	
Steps	Examples
1. Plan an experiment	- Determine the possible variables - Determine the variable to be measured - Break the experiment down into steps
2. Conduct the experiment	- Prepare an apparatus for the experiment - Perform a set of tasks - Make observations or take measurements
3. Interpret the results	- Process the data collected - Establish relationships - Discuss possible errors

Observation Method	
The scientific method of observation helps observers to interpret facts on the basis of predetermined criteria and generally accepted elements within a given field. In light of the information collected, observers gain a new understanding of the facts, which is inextricably linked to the context in which the observations were made. Based on the way they interpret and organize information, the observers reinterpret the world, taking into consideration their prior knowledge and the conceptual schemes that they apply to the facts observed.	
Steps	Examples
1. Plan the observation	- Determine the observation criteria - Prepare an observation checklist
2. Gather information	- Gather information, referring to the observation criteria
3. Interpret the information	- Organize the information in order to explain the phenomenon or the situation - Make connections between the items of information gathered

Modelling	
Modelling consists in constructing a concrete representation of an abstract situation that is difficult to observe or impossible to see. A model must help people understand a given reality, explain certain properties of what it attempts to represent and help people predict new phenomena. The model can take different forms: a text, a drawing, a mathematical or chemical formula or equation, a software program or a scale model.	
Steps	Examples
1. Develop a model	- Identify the components and the relationships between them - Choose the method of representation
2. Build the model	- Make a scale model or a diagram - Develop a formula
3. Validate the model	- Identify possible contradictions and inconsistencies - Verify the model's validity - Make changes or go back to the preceding steps, if necessary

Documentary Research	
Documentary research is a methodical procedure for collecting and interpreting information. Researchers must define their goal and know what type of documents they are looking for, where to find them and how to choose the appropriate ones. The aim is to construct a solid argument based on facts from reliable sources.	
Steps	Examples
1. Plan the research	- Choose the sources to consult - Decide on the type of document to look for, key words and search tools - Make a list of words and related terms characterizing your search
2. Consult literature	- Find the literature - Evaluate its relevance, given the goal of the research - Gather specific information - Establish a preliminary plan for your report
3. Establish a definitive plan for your report	- Flesh out the preliminary plan in light of additional information - Develop your theme, hypothesis, main ideas and secondary ideas

Appendix 4

Key Features and Manifestations of the Competencies

Competency 1: Seeks answers or solutions to problems involving biology	Competency 2: Makes the most of his/her knowledge in biology	Competency 3: Communicates ideas relating to questions involving biology, using the languages associated with science and technology
Defines a problem • Determines the elements that seem relevant • Determines the relationships between the different elements • Reformulates the problem in terms of biology concepts • Formulates realistic hypotheses or possible solutions **Develops a plan of action** • Chooses a hypothesis or a solution • Determines the necessary resources • Plans the steps involved in implementing the plan of action **Carries out the plan of action** • Handles equipment and substances and carries out planned operations • Gathers potentially useful data or observations • Adjusts the plan of action or its implementation, if necessary **Analyzes his/her results** • Processes the data gathered or his/her observations • Looks for significant patterns or relationships • Makes connections between his/her results and biology concepts • Judges the appropriateness of the answer or solution found • Formulates new hypotheses or solutions, if applicable	**Puts issues in context** • Defines the contextual aspects of the issue (e.g. social, economic, environmental, historical) • Identifies ethical considerations associated with the issue • Determines the phenomena or applications related to biology **Analyzes a phenomenon or an application from a biological point of view** • Describes a phenomenon or application qualitatively or quantitatively. • Recognizes the biological concepts, laws, theories, principles and models involved in the phenomenon or application. • Explains biological concepts, laws, theories, principles and models. • Makes connections among biological concepts, laws, theories, principles and models. **Explains an issue from the standpoint of biology** • Develops an explanation based on concepts, laws, theories, principles and models of biology • If applicable, establishes connections with other issues involving the same elements • Justifies his/her explanation **Forms an opinion about an issue** • Determines the elements that can help him/her form an opinion • Gathers information on these elements from different sources • Compares different points of view • Supports his/her opinion with the elements considered • Qualifies his/her opinion, taking others' opinions into account	**Interprets scientific and technological messages** • Places the message in context • Makes sure the sources are reliable • Selects the elements needed to interpret the message • Grasps the precise meaning of words or statements • Establishes connections between concepts and their graphical or symbolic representations **Produces scientific and technological messages** • Structures his/her message • Uses scientific and technological vocabulary • Uses the symbolic and graphical languages associated with science and technology • Adheres to established standards and conventions for the different languages • Demonstrates rigour and coherence • Respects intellectual property rights

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