

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
<ul style="list-style-type: none"> ▪ Defines a problem ▪ Develops a plan of action ▪ Carries out the plan of action ▪ Analyzes his/her results 	<ul style="list-style-type: none"> ▪ 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 	<ul style="list-style-type: none"> ▪ 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.

The Living World	
General concept: Cell division	
<p>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.</p> <p>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.</p> <p>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.</p> <p>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).</p> <p>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.</p>	
COMPULSORY CONCEPTS	PREVIOUSLY ACQUIRED KNOWLEDGE
Cells <ul style="list-style-type: none"> Cellular components Cell membrane Nucleus Chromosomes, genes 	<i>Identifies the main cellular components visible under a microscope (cell membrane, cytoplasm, nucleus, vacuoles)</i>
	<i>Describes the role of the main cellular components visible under a microscope</i>
<i>Mitosis</i>	<i>Describes the functions of mitosis (reproduction, growth and regeneration)</i>
<i>Functions of cell division</i>	<i>Distinguishes the functions of mitosis from those of meiosis</i>
<i>Meiosis and the sexual life cycle: meiosis, fertilization</i>	<i>Describes the function of meiosis (gamete production)</i>
	<i>Indicates the advantages of the sexual life cycle (e.g. the mixing of genes from parents, the difference between parents and their offspring)</i>

COMPULSORY CONCEPTS	KNOWLEDGE TO BE ACQUIRED
Cell cycle <ul style="list-style-type: none"> ○ Interphase ○ 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 oogenesis
	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	
<p>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.</p> <p>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.</p> <p>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.</p>	
COMPULSORY CONCEPTS	PREVIOUSLY ACQUIRED KNOWLEDGE
<i>Genetic diversity</i>	<i>Associates genetic diversity with sexual reproduction (the combining of genes from the mother and father ensures diversity)</i>
COMPULSORY CONCEPTS	KNOWLEDGE TO BE ACQUIRED
Reproductive system <ul style="list-style-type: none"> 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 gonadoliberein (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 gonadoliberein [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 gonadoliberein [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 <ul style="list-style-type: none"> ○ Spermatogenesis ○ 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 <ul style="list-style-type: none"> ○ Hormonal ○ Mechanical barrier ○ 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	
<p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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).</p>	
COMPULSORY CONCEPTS	PREVIOUSLY ACQUIRED KNOWLEDGE
<i>Tissues</i>	<i>Defines a tissue as a set of identical or non-identical cells that work together to perform a common function in an organism</i>
<i>Organs</i>	<i>Defines an organ as a differentiated part of an organism that is composed of tissues and that performs one or more specific functions</i>
<i>Systems</i>	<i>Defines a biological system as a set of cells, tissues or organs that perform one or more common functions</i>
	<i>Describes the main functions performed by the human body (nutrition, relationships, reproduction)</i>

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 <ul style="list-style-type: none"> ○ Embryonic period ○ 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

The Technological World	
General concept: Biotechnology	
<p>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.</p> <p>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.</p> <p>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."</p>	
COMPULSORY CONCEPTS	PREVIOUSLY ACQUIRED KNOWLEDGE
Cell cultures	<i>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)</i>
COMPULSORY CONCEPTS	KNOWLEDGE TO BE ACQUIRED
Prenatal diagnosis <ul style="list-style-type: none"> ○ DNA screening tests ○ Diagnostic tests 	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)
	Analyzes prenatal screening and diagnostic techniques (e.g. blood sampling from the mother, ultrasound, amniocentesis, chorionic villus sampling)
Medically assisted procreation	Describes the physiological and mechanical basis of various medically assisted procreation techniques, such as artificial insemination, embryo transfer, <i>in vitro</i> fertilization (ovarian stimulation, egg retrieval, intracytoplasmic injection)
Intervention techniques used for reproduction mechanisms	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)

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 <ul style="list-style-type: none"> - Observational drawings 	<ul style="list-style-type: none"> • 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 <ul style="list-style-type: none"> - Use of laboratory materials - Use of observational instruments - Preparation of samples 	<ul style="list-style-type: none"> • 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) • Uses observational instruments (e.g. microscope, binocular, magnifying glass) appropriately • 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 <ul style="list-style-type: none"> - Microscope Human Reproduction <ul style="list-style-type: none"> - Birth control pill - Emergency contraceptive pill - Fertility test Development <ul style="list-style-type: none"> - Pregnancy test - Bone marrow transplant Biotechnology <ul style="list-style-type: none"> - 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 <i>in vitro</i> 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
<ul style="list-style-type: none"> ▪ 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 	<ul style="list-style-type: none"> ▪ Formulation of appropriate questions ▪ Relevant use of scientific and technological knowledge ▪ Appropriate formulation of explanations or solutions 	<ul style="list-style-type: none"> ▪ Accurate interpretation of scientific messages ▪ Appropriate production or transmission of scientific messages

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