Biotechnology

Learning Continuum

Grades 7 to 12

Toronto District School Board

BioTalent™ Canada

Building skills for Canada's bio-economy

let's talk science

inspiring discovery

What is Biotechnology?

Biotechnology is the application of science and technology to living organisms. It is comprised of such core technologies as DNA/RNA applications, protein and peptides/enzymes, cell and tissue culture and engineering, gene and RNA vectors, bioinformatics, nanobiotechnology, process biotechnologies, and sub-cellular processes.

What is the Bio-economy?

The bio-economy involves the research, development, manufacturing and commercialization of technologies and products for such areas as:

Agriculture	Environment	Life sciences
Aquaculture	Food processing	Medical devices
Bioenergy	Forestry	Natural resources
Bioinformatics	Genomics	Nanotechnology
Bioproducts	Human and animal health	Nutraceuticals
Biosciences	Industrial	Pharmaceuticals

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Introduction

This document outlines a framework to assist educators and curriculum and resource developers in providing Canadian students with opportunities to develop awareness and understanding of biotechnology.

Biotechnology is a business sector and scientific discipline which deals with the use of living organisms or their products in industrial processes. It is a group of related technologies that is used by many industries.[1]

The purposes of the *Biotechnology Learning Continuum, Grades 7 to 12* are:

- to identify opportunities for teachers, resource developers and curriculum developers to develop units, lesson plans and learning resources about biotechnology;
- to support the implementation of existing curriculum requirements within the context of biotechnology; and
- to be used as a resource by curriculum developers for future curriculum revisions to ensure that students develop an understanding of biotechnology and its current and future impact on our lives.

Typically, learning about biotechnology is usually found in specialized courses at the senior level in science or in technology education; however, understanding biotechnology is not the sole domain of any subject discipline or the senior grades.

Biotechnology is interdisciplinary and the structure and organization of the *Biotechnology Learning Continuum, Grades 7 to 12* is not specific to one or two subject areas. Biotechnology involves the interactions of business and research and has legal, political, philosophical, ethical, societal and environmental implications.

[1] BioTalent Canada. *Making Sense of Biotechnology*. Presentation workshop to Toronto District School Board. 13 January 2010.

Structure of this Document

This document is organized into six parts and is designed to complement jurisdictional curricula.

- **Part One: Biotechnology in Our Lives** provides an introduction about the importance of biotechnology in our lives and illustrates the interdisciplinary nature of biotechnology with an example related to stem cells.
- **Part Two: Using the *Biotechnology Learning Continuum, Grades 7 to 12*** provides direction on how to use this document.
- **Part Three: Careers in Biotechnology** provides a broad overview of the range of careers in biotechnology industries and research. Included in this part is a summary of career path competencies based on Human Resources and Skills Development Canada's (HRSDC) Essential Skills and related skill competencies that are common to most subject disciplines with contextualized examples related to biotechnology.
- **Part Four: Interactions and Variation Overviews** provides a summary of the big ideas and related understandings for each of the two content organizers: Interactions Organizer and Variation Organizer. Each set of these Organizers' respective understandings are grouped as Emerging, Developing and Advanced. Each grouping builds towards and understanding of the big idea. Emerging Understandings are appropriate for grades 7 and 8; Developing Understandings target grades 9 and 10; and Advanced Understandings target grades 11 and 12. However, all groups of Understandings can also be considered as a sequence of prior knowledge towards the big ideas of their respected associated Organizer.
- **Part Five: Big Ideas, Understandings and Learning Opportunities** is a reorganization of Part Four with a separate section for each of emerging, developing and advanced understandings. This part includes key questions and activity examples related to each big idea.
- **Part Six: Canadian Contributions to Biotechnology** highlights the contributions of many Canadians. Each name has a short descriptor of their contribution and a weblink for further information.

The document also contains a **Glossary**.

Part One: Biotechnology in Our Lives

Biotechnology matters.

Every day Canadians use, manufacture and export thousands of products, technologies and applications that are a result of biotechnology. Biotechnology is an important contributor to the bio-economy. Its products, technologies and applications are part of our daily lives, from food products like beer, seedless fruits and fermented foods such as cheese and yogurts to compostable plastic bags to special drugs and vaccines.

Biotechnology has its roots in the distant past. Humans have been selectively altering parts of living organisms for centuries. Plants have been selectively bred for increased yields and to be disease-resistant. Animals have been bred for increased milk, meat or egg production. Techniques used in manufacturing beers, wines and cheeses were well-known for centuries, but understanding the science behind their molecular nature was not.

In the mid-1970s, developments in recombinant DNA techniques and new technologies led to rapid growth and advances in our understanding of molecular biology. Today genomics is giving us a remarkable understanding of and control over biological processes.

Becoming aware about biotechnology is important for today's students. They are the consumers, farmers, inventors, entrepreneurs, business professionals, scientists, engineers, technicians and politicians of the future. As future citizens they will be faced with moral, ethical and philosophical issues regarding the use of the products, technologies and applications of biotechnology. Its impact and effects on their lives is difficult to predict.

Biotechnology is a significant part of global bio-economy industries that focus on biological products, technologies, tools and applications in the production of treatments, diagnostics, foods, energy, chemicals and materials.[2] Career opportunities in biotechnology industries span a vast range of scientific and non-scientific fields, although careers in non-scientific areas benefit from an interest in and some understanding of the science that underpins the work of biotechnology industries. Many of these careers were not imaginable a couple of decades ago and new discoveries will undoubtedly lead to future careers that are presently unforeseen.

[2] BIOTECanada http://www.biotech.ca/en/what-biotech-is/bio-based-economy.aspx (Accessed April 9, 2010)

Interdisciplinary Example: **Cord Banks**

As parents experience the joy of having a newborn, they are faced with a new decision - what to do with their child's umbilical cord. In past years, the umbilical cord was treated as medical waste, but it has recently been discovered that umbilical cord blood is rich in stem cells.

Stem cells are unspecialized cells that have the potential to become specialized cells (e.g., red or while blood cells, liver cells, etc.). Stem cells in umbilical cords are the most "naïve" stem cells in the body and are created during the earliest phases of development. The potential of using stem cells in the treatment of a wide variety of diseases and medical conditions has led to public and private stem cell storage.

Today's parents are presented with a choice as to whether or not they want to cord bank their newborn's stem cells and, if they do, whether to choose a public cord bank or a private cord bank.

Business Studies

What regulations govern stem cell collection and use in Canada? The USA? Other countries? What regulations should be in place to govern stem cell collection and use in Canada? The USA? Other countries?

Language Arts/ English

How does literature present issues related to stem cells (e.g., Chimera by Wendy Lill, My Sister's Keeper by Jodi Picoult)?

How are stem cell research and issues related to stem cell use portrayed in the media? What criteria are used to assess the authority, reliability and validity of this information?

Politics

Should government have a role in directing stem cell research and use? If so, what should this role be? At what level of government should it be decided? Who decides?

Law

Who owns stem cells? What are the legal implications when stem cells have commercial value in the bio-economy?

Family Studies/Parenting

How do parents make an informed decision on whether or not to use a public or private cord bank for their newborn's stem cells?

World Religions

How can different religions influence the ways in which individuals and families think about the issues that will have consequences on the formation and expression of opinion, thereby informing political and legal views?

Science

How can stem cells be used to better understand the development of genetic disease? Are stem cells in plants different than animals? How are plant stem cells used?

Part Two: Using the Biotechnology Learning Continuum, Grades 7 to 12

The *Biotechnology Learning Continuum, Grades 7 to 12* is organized to emphasize a continuum of biotechnology learning opportunities across disciplines for intermediate and senior students.

The *Biotechnology Learning Continuum, Grades 7 to 12* is designed to be flexible to meet the diversity of Canada's education systems. Each Canadian province and territory has its own education system. This includes government-mandated curriculum, organization of grade divisions and graduation requirements.

Jurisdictional government curricula provide direction on focus and the depth of understanding that is expected for their students. The *Biotechnology Learning Continuum, Grades 7 to 12* supports existing curriculum and provides biotechnology contexts.

Focusing on Competencies

Biotechnology careers and workplace opportunities encompass many curriculum requirements that focus on skills.

Part Three identifies careers in biotechnology and competencies based on Human Resources and Skills Development Canada (HRSDC) Essential Skills and on research and scientific experimentation competencies.

Career Path Competencies are interdisciplinary and organized around:

- Communication
- Computer Use
- Personal Management
- Thinking

Research and Scientific Experimentation Competencies are organized around:

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communicating Results
- Reflecting on the Process

Learning suggestions of what students might be doing within a biotechnology context have been provided for these competencies.

All competencies have a skills focus and students continuously develop these at different levels of complexity as they progress throughout their school years. Differentiation occurs in the classroom through the choice of grade- or age-appropriate resources or through biotechnology learning resources that may be developed using this *Continuum*.

Focusing on Interactions and Variation Organizers

Parts Four and Five provide direction to develop lessons, units, courses and resources with a focus on the science of biotechnology and on biotechnology contexts.

Part Four has an overview of the big ideas and emerging, developing and advanced understandings of the **Interactions** and **Variation** organizers.

The **Interactions** continuum focuses on biotechnology in business, societal and environmental contexts.

These understandings are interdisciplinary and relate to curriculum requirements in a variety of subject disciplines.

Big ideas and Understandings are organized around:

- The Business of Biotechnology
- Biotechnology and the Public
- Biotechnology and the Environment

The **Variation** continuum focuses on our understandings of living organisms and is related to curriculum requirements predominantly in science, biology and biotechnology in technological education.

For non-science disciplines, **Variation** provides a general overview of the science related to biotechnology.

Big ideas and Understandings are organized around:

- Cells and Molecular Biology
- Genetics
- Biodiversity

Part Five is a reorganization of Part Four with additional key questions and student applications for each big idea.

Big ideas for both **Interactions** and **Variation** are reorganized into three sections of emerging, developing and advanced understandings. Emerging understandings are generally intended for grades 7 and 8, developing understandings for grades 9 and 10 and advanced understandings for grades 11 and 12; however, they could also be considered as a sequence of prior knowledge towards understanding the big ideas within each of these content organizers.

Some users of this resource may prefer to see the continuum of big ideas and understandings at a glance (**Part Four**) and some may prefer to have additional direction within each of the continuum areas (**Part Five**).

Part Three: Careers in Biotechnology

Careers in biotechnology are part of the bio-economy and involve the research, development, manufacturing, sales and commercialization of technologies, products and applications in areas such as:

Resource Industries	Product Industries	Bioscience and Human Health
Agriculture	Food processing	Bioinformatics
Aquaculture	Industrial chemicals	Genomics
Bioenergy	Nutraceuticals	Human health
Environment	Pharmaceuticals	Life sciences
Forestry	Textiles	Medical devices
Mining		Nanotechnology

Source: BioTalent Canada. *Making sense of Biotechnology*. Workshop to Toronto District School Board, 13 January 2010.

Career opportunities in the above biotechnology industries span a vast range of scientific and non-scientific fields. Careers in non-scientific areas of biotechnology industries benefit from an interest in and some understanding of the science of biotechnology. All benefit from having the skills to communicate in the language of biotechnology to both specialists and non-specialists.

Below are some examples of the range of careers. Many of these are not limited to biotechnology, but they have a role in biotechnology industries and research.

Distribution/ Logistics/ Supply Chain	Information Technology	Communications	Financial Affairs	Clinical Research	Purchasing
Distribution Manager	Data Analysis	Communications Director	Account Manager	Clinical Research Assistant	Farm Product Purchaser
Maintenance Technician	Data Entry	Healthcare Communication Specialist	Accountant	Clinical Researcher	Planner/Buyer
Plant Manager	Information Systems Manager	Science Information Officer	GCP Auditor	Laboratory Technician	Purchasing Manager
Receiver Materials Handler	Technical Support	Staff Writer	Health Economist	Preclinical Technician	
Supply Chain Manager	Bio-Strategy Consultant	Scientific Writer	Manager of Investor Relations	Clinical Project Manager	

Research and Development	Administration/ Operations/ General Management	Manufacturing	Marketing/ Sales/ Customer Service	Quality Control/ Assurance	Other Career Areas
Biochemist	Administrative Director	Biochemical Development Engineer	Customer Service Representative	Documentation Coordinator	Bioethics
BioFuels Agriculture Crop Specialist	Agricultural and Forestry Supervisor	BioDiesel Pretreat Operator	Marketing Manager	Quality Assurance Technician	Bioinformatics
BioJet Fuel Research Director	BioDiesel Manager	Electrical Engineer	Marketing/Sales/ Customer service	Quality Control Specialist	Field Research
Biomass Gasification Specialist	Business Development Director	Enzymatic Engineer	Medical Sales Representatives	Safety Officer	Genetic Counselling
Director of Research	Chief Executive Officer	Manufacturing Assistant	Sales Manager		Intellectual Property
Laboratory Technician	Planning and Scheduling Engineer	Mixing and Blending Machine Operator	Sales Representative		Regulatory Affairs
Plant Breeder	Privacy Officer	Thermochemical Engineer			
Process Engineer	Project Manager	Vice-president of Manufacturing			
Animal Technician	Trainer				
Aquatic Ecologist	Leadership Coach				
Research Scientist	Library Manager				
Statistician					

Source: Adapted from BioTalent Canada. (no date) *Generating opportunity* and BioTalent Canada skill profiles http://www.biotalent.ca/default_e.asp?id=78 (accessed April 6, 2010) and other biotechnology career web sites.

Career Path Competencies

Whether career choices are science-related or non science-related, they require competencies related to communication, proficient computer use, interpersonal relationships and the ability to work well independently and cooperatively in diverse teams, as well as critical and creative thinking. These competencies are common to most workplaces and encompassed within Human Resources and Skills Development Canada's (HRSDC) Essential Skills (reading text, document use, writing, oral communication, numeracy, working with other, thinking, computer use, continuous learning).[3]
This document is organized into four career path competencies:

- Communication
- Computer Use
- Personal Management
- Thinking

The **Competencies** for each of these four areas are outlined below. They occur in curricula across grades and across subject disciplines. Students engage and continue developing these competencies at different levels of complexity as they progress throughout their school years. Differentiation of these competencies occurs in the classroom or through biotechnology learning resources developed using this *Continuum*. **Learning Suggestions** provide examples of how these competencies could be developed within a biotechnology context in the classroom.

Communication

Description	Competencies	Learning Suggestions
Using discipline-specific terminology correctly and accurately to specialists and non-specialists.	Use terminology accurately to explain concepts and issues to specialists and non-specialists.	Students can write research reports and prepare and deliver oral and multimedia presentations on biotechnology topics to science specialists. Students can write reports and business plans and prepare and deliver oral and multimedia presentations related to biotechnology to non-science specialists.

[3] Further information about HRSDC Essential Skills can be found at http://www.rhdcc-hrsdc.gc.ca/eng/workplaceskills/essential_skills/general/home.shtml (accessed April 6, 2010).

Description	Competencies	Learning Suggestions
Reading, interpreting and understanding text including print and non-print media.	Read and interpret for meaning a wide variety of informational texts in print and non-print media, and support interpretations with well-chosen ideas (stated and implied) from the texts. Analyze and evaluate the effectiveness of tables, charts and graphs to support ideas and information. Assess the authority, reliability and validity of print and non-print informational texts.	Students can research biotechnology topics for a variety of purposes, including essays, presentations, projects, op-ed articles and reports. Students can conduct critical analysis of biotechnology-related media reports and scientific publications.
Writing in various forms and using a variety of media, for specific purposes and to specific audiences.	Generate, gather and organize ideas and information to write for specific purposes and to specific audiences. Edit, revise and proofread to produce well organized and grammatically correct written work. Record information accurately using diagrams, tables, graphs, jot notes, outlines or charts appropriate to the purpose and audience.	Students can write lab reports, essays, op-ed articles, research reports and multimedia presentations on biotechnology topics (e.g., communications plans, scientific investigations, business plans, feasibility studies, etc.).
Communicating orally to exchange ideas and information for specific purposes and to specific audiences.	Use a variety of speaking strategies to communicate in a clear and coherent manner for a range of purposes using language appropriate for the topic and intended audience. Use different audio-visual aids to support and enhance oral presentations to engage the intended audience for a specific topic. Use active listening strategies when participating in discussions or making presentations (e.g., appropriate body language, eye contact, ask questions for clarification, etc.).	Students can deliver oral presentations of primary and secondary research into biotechnology topics to both science specialists and non-science specialists. Students can enhance oral presentations of primary and secondary research into biotechnology topics using a variety of audio-visual aids. Students can effectively participate in debates and town hall meetings related to biotechnology topics.

Description	Competencies	Learning Suggestions
Using numbers and quantitative terms as required.	Select and apply the appropriate representations of mathematical ideas for the intended purpose (e.g., pictorial, graphical, algebraic, numeric, geometric, etc.). Apply a variety of data management tools and strategies to make convincing arguments about data. Recognize arguments based on faulty, incomplete or misleading uses of numbers (i.e., average results are reported but not the amount of variation around the average, a percentage of fraction is given, but not the total sample size (as in 9 out of 10 dentists recommend), absolute and proportional quantities are mixed or results are reported with overstates precision (13 out of 19 students as 68.42%). Estimate and measure accurately using Système International (SI) and other standard units to make accurate calculations and measurements for various applications.	Students can generate and present quantitative data related to biotechnology topics in a variety of formats. Students can make reasonable estimates and accurate measurements using standard units while conducting investigations of biotechnology topics. Students can generate budgets, financial statements, proposals, statistical trends and projections using appropriate formats and in a variety of formats (e.g., graphs, spreadsheets, etc.) for business plans related to biotechnology topics.

Computer Use

Description	Competencies	Learning Suggestions
Computers are standard tools used in most workplaces.	Demonstrate a grade-appropriate proficiency level in keyboarding skills on alphanumeric keyboards. Demonstrate proficiency in using industry-standard software (i.e., word processing, spreadsheet, database, presentation and desktop publishing) appropriate to a task. Identify guidelines for effective websites (e.g., design, technical requirements, appropriate language and inclusive images, etc.). Demonstrate effective and appropriate use of email software and social media.	Students can use computers to conduct accurate primary and secondary research related to biotechnology topics, manipulate and present data in a variety of effective ways and communicate electronically about biotechnology issues.

Personal Management

Description	Competencies	Learning Suggestions
Personal management skills are important for personal and career growth.	Demonstrate positive attitudes and behaviours towards themselves and others. Demonstrate responsibility for chosen actions. Demonstrate work habits that ensure personal safety and the safety of others.	Students can work positively and constructively with others while investigating biotechnology topics. Students can follow appropriate safety and ethics guidelines while investigating biotechnology topics.
Understanding your learning style, including your weaknesses, strengths and goals, is important for lifelong continuous learning.	Demonstrate self-direction in learning, goal setting and goal achievement. Apply skills of metacognition, reflecting upon what they have learned and what they need to learn. Describe personal attributes that make it possible to work in enterprising ways with other people on projects and tasks.	Students can work independently and effectively towards self-set goals while investigating biotechnology topics. Students can identify effective work habits and areas for improvement experienced while investigating biotechnology topics.
Being an effective team member and an effective leader is essential in contributing productively in working with others to carry out tasks or projects.	Work cooperatively with group members to develop and carry out a plan/project/investigation/experiment. Create formal and informal strategies to effectively resolve disputes within a team and if required with others external to the team (i.e., stakeholders). Develop leadership skills by assuming specific roles and responsibilities in projects and investigations. Recognize that people have different learning styles, personalities and experiences which can contribute to the group. Identify behaviours and attitudes that contribute to or pose obstacles to cross-cultural understanding. Elicit, clarify and respond to questions, ideas and diverse points of view in discussions. Provide and accept constructive feedback within a team situation.	Students can effectively adopt a variety of roles and responsibilities while investigating biotechnology topics. Students can employ a variety of group management skills to ensure effective and meaningful participation by all members in a group while investigating biotechnology topics. Students can delegate expertise among each other to successfully complete a given task. Students can seek clarification of group assignment requirements before and during completion of a task.

Thinking

Description	Competencies	Learning Suggestions
Critical thinking and deductive reasoning differentiates between different types of cognitive functions that are interconnected (e.g., problem-solving, decision making, job task planning and organizing, significant use of memory and finding information).	Construct arguments to support a decision, using evidence and recognizing various perspectives. Developed reasoned arguments supported by historical and contemporary evidence. Identify and criticize the reasoning in arguments in which fact and opinion are intermingled or where the conclusions do not follow logically from the evidence given. Recognize overgeneralization when basing results and conclusions on only a few observations. Evaluate, critically, ideas, information and positions from multiple perspectives. Recognize that decisions reflect values and consider their own values and those of others when making a decision.	Students can construct and effectively deliver effective, evidence-based arguments that will be persuasive to both specialist and non-specialist audiences while investigating biotechnology topics. Students can critically evaluate the arguments of themselves and others in terms of accuracy and depth of evidence and values while investigating biotechnology topics.
Creative thinking involves skills such as flexibility, elaboration, brainstorming, modification and associative thinking.	Generate creative ideas and strategies in individual and group activities. Describe how enterprising employees can apply creative or innovative thinking to make a business more competitive. Apply creative-thinking strategies (e.g., mind mapping, brainstorming, etc.) to determine possible solutions to unsatisfied needs and wants in the school or the community.	Students can apply a variety of individual and group creative thinking strategies to generate innovative solutions to both research and business challenges while investigating biotechnology topics.

Research and Scientific Experimentation Competencies

Research is based on active discovery involving observation, inference, gathering evidence and presenting and debating results. **Scientific Experimentation** for hypothesis and goal-oriented problem-solving uses various technologies, techniques and tools and are integral to advances in biotechnology.

Competencies related to research and scientific experimentation are developed across grades and across subject disciplines. Learner requirements are well-represented in existing curriculum documents. A brief summary of the stages of research and scientific experimentation are outlined below and can be developed through relevant biotechnology contexts.

Research and Scientific Experimentation Stages	Related Competencies
Initiating and Planning	Identify focused questions to investigate. Outline a plan appropriate for the investigation. Identify possible information sources. Identify and control variables, if applicable.
Performing and Recording	Follow plan while adapting to unforeseen circumstances. Select appropriate information resources, materials and/or equipment. Take notes and record information in an appropriate manner. Handle materials and/or equipment competently with due regard for safety of self and others. Work in an ethical manner regarding using specimens, acknowledging data sources and authenticity of results.
Analyzing and Interpreting	Process data and information appropriately. Identify and suggest explanations for discrepancies in data. Draw valid conclusions, allowing for uncertainties or errors. Evaluate sources of information, showing awareness of currency and bias.

Research and Scientific Experimentation Stages	Related Competencies
Communicating Results	Present data and information appropriately. Formulate an opinion and support it using reasoning. Communicate conclusions appropriate to the investigation. Use terms accurately and in context. Cite references and sources of information.
Reflecting on the Process	Evaluate the process and plan, identifying weaknesses and developing realistic strategies for improvement. Identify experimental error related to sample size, equipment and experimental process used. Recognize the imprecise nature of all measurements, as applicable to the investigation. Identify knowledge and skills that have been learned. Identify new topics or questions for further investigation.

Part Four: Interactions and Variation Overviews

Interactions

Biotechnology involves interactions of biotechnology businesses, industries and research with society and the environment. Big ideas and understandings for **Interactions** are organized around:

- The Business of Biotechnology
- Biotechnology and the Public
- Biotechnology and the Environment

The Business of Biotechnology

Big Idea:	**Companies in various biotechnology industries participate in processes or parts of processes to develop a diverse range of products, tools and services.**	
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
Biotechnology products and tools are based on scientific knowledge related to organisms' products or their parts. Criteria are necessary for assessing the feasibility of taking ideas through an extensive process to make functional products. Biotechnology companies employ a wide range of skilled workers in diverse careers. Human resources is an area that focuses on processes and activities related to employees and employers. Biotechnology products and services raise ethical considerations.	It takes many years of discovery, research, exploratory development and full development before an idea becomes a biotechnology product that is approved for use. Companies spend millions (and sometimes billions) of dollars in research and development when producing a new product for the marketplace. Financial factors such as risk assessment and return on investment are major considerations to bring a product to the marketplace. The development of a product is integrated with compliance to regulatory requirements. Regulations ensure the safety and efficacy of biotechnology products. Human resources involves acquiring and sustaining a dedicated workforce.	Some basic requirements for biotechnology companies are similar to other businesses, such as developing: feasibility studies; venture plans; marketing plans; financial plans; business plans; work plans; human resources strategies; investment funds; governance policies; and production costs (e.g., land/real estate, labour, etc.). There are different business models in biotechnology based on the nature of the company (e.g., products, services, therapeutics, consulting, data generation, etc.). Countries can have different regulations pertaining to biotechnology (e.g., bovine growth hormone is approved for use in dairy cattle in United States but not in Canada, etc.).

Big Idea:	**Intellectual property (IP) protection plays a central role in biotechnology innovation.**	
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
Intellectual property is the result of ongoing innovations and creativity. Intellectual property can be a product, a composition, a piece of equipment, a process or an improvement on any of these. Intellectual property is based on the legal right of the owners to exclude others from using the "property."	There are different types of intellectual property rights, including patents, trademarks, copyrights, industrial designs and integrated circuit topography. Many intellectual property rights are modifications of existing products and processes. Owning the rights to organisms' products, parts of organisms or processes involving organisms and their parts raises ethical issues.	Patents help to secure the business potential of innovative ideas (e.g., competitive edge, blocking others from entering the market, trade with other companies, reputation as innovators to investors, etc.). Patents are essential for protection of marketing rights and financing. A new era of intellectual property considerations are emerging which emphasizes working cooperatively through sharing and collaboration instead of increased protection.

Big Idea: Biotechnology discoveries, processes, products and services have ethical implications.		
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
Ethical questions are different from research questions and legal questions. Ethical considerations include respect for people, minimizing harm while maximizing benefit and ensuring fairness. People's different beliefs, values and life experiences can shape their position about ethical issues. Ethical considerations include the procurement, use and care of animals involved in the research, development and production of biotechnology processes, products and services.	Ethical considerations should be examined from multiple perspectives so that solutions are thoroughly considered and are morally grounded, fair, just and reasonable (e.g., research ethics review boards, guidelines for the care and use of experimental animals, farm animals, fish and wildlife, etc.). Bioethics is a multidisciplinary branch of ethics related to life sciences. Bioethicists can be involved in research programs, clinical committees, law practices, regulatory reviews and policy-making.	The *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* governs research ethics protocols in Canada and the Canadian Council on Animal Care sets and maintains standards for the care and use of animals used in research, teaching and testing throughout Canada. Addressing ethical questions distinguishes between relevant and irrelevant facts and courses of action are based on critical reasoning skills. Justifications of courses of actions related to ethical considerations include both positive and negative impacts on multiple stakeholders and how they could be affected.

Biotechnology and the Public

Big Idea:	**Communication about advances in biotechnology and biosciences research is important for public awareness and understanding about related issues that impact their lives.**	
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
Different means of communication may be better suited to one audience over another depending on the purpose of the communication (e.g., scientific research journals for scientists, town hall meetings for the general public, etc.). Surveys are often used as a means of gathering information about the public's perceptions and attitudes towards biotechnology research and industries. The media is a major source of communication to the general public.	Different stakeholders shape public perceptions about biotechnology (e.g., journalists, industry public relations and marketing managers, scientists, special interest groups, health care providers, politicians, etc.). Communication technologies are influencing ways people access and share information (e.g., blogs, websites, RSS feeds, Twitter, etc.). Mass media can impact and influence public information about biotechnology issues and ideas.	Communication about biotechnology-related issues requires accurate and current information, including the uncertainties of the research and the potential impacts on society. Communication on biotechnology-related issues must be open to society's response to the potential impacts and ethical considerations of these issues. Policymakers and politicians are influenced by how the public responds to biotechnology issues.

Big Idea:	**The results of biotechnology innovations and biosciences research range from those that are highly controversial to those that are well accepted and considered essential to our lives.**	
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
Many products commonly used on a daily basis are due to biotechnology innovations and biosciences research (e.g., living cells are used to make beer, wine, bread, yogurt and cheese; enzymes are used in textiles to replace harsh chemicals in manufacturing processes; etc.). Understanding about the structure and function of cells and tissues has brought about improvements in human health, food production and nutrition.	Some biotechnology products and services are highly controversial (e.g., genetically-modified plants, cloning, using stem cells from embryos, etc.). Some biotechnology products and services are well accepted and considered essential (e.g., production of insulin through genetically-modified bacteria, bioremediation, harvesting and processing forest fibre, etc.).	Humans have exploited and manipulated biodiversity since the Green Revolution to develop and preserve food products used for human consumption (e.g., bacteria to ferment and preserve foods, selective breeding of grain crops for higher yields and hardiness, specialized breeds of cattle for milk or meat production, etc.). Continued advances in health-related biotechnologies (e.g., nanobiotechnology, therapeutics, diagnostics, etc.) play an important role as a preventative tool in Canada's health care system and will continue to raise ethical and philosophical issues (e.g., personalized medicine, stem cell therapies, etc.).

Biotechnology and the Environment

Big Idea:	**Biotechnology industries and biosciences research contribute to efficient and environmentally responsible use of natural, human and economic resources.**	
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
Biotechnology applications are found in environmental sectors (e.g., bioremediation, phytoremediation, managing soil structure and fertility, etc.). Bio-based fuels are being investigated as a source of alternative energy. Biotechnology products, technologies and applications can impact the environment depending on human wants and needs (e.g., use of oil eating bacteria to clean up oil spills vs. cost and effort involved, etc.).	Biotechnology industries contribute to finding solutions for the sustainability of terrestrial and aquatic ecosystems (e.g., biopesticides, treatment of waste water effluent, use of DNA fingerprinting to manage wild fish stocks, etc.). New biotechnology products, technologies and applications have both risks and benefits to sustainability. Genetic modification of plants and animals is used by agricultural biotechnology firms to combat the growing challenges presented by drought and malnutrition, and to decrease the environmental impact of agriculture.	Biotechnology innovations are one way of protecting diversity of species. Bioresources support efforts to produce renewable energy (e.g., biodiesel is a fuel source produced from plant and animal fats; new sources of fuel may be possible by turning "on" genes that regulate growth to improve yields for biofuel crops, etc.). Genome sequencing projects can lead to improvements in yield and quality of food crops, including enhanced disease and insect resistance and improved performance under drought, saline or heat-stressed conditions. The benefits achieved through biotechnology have not been equally shared by all peoples and all societies.

Variation

Variation is a key concept in the natural world. Understanding and appreciating variation is critical to biotechnology. The big ideas and understandings for Variation are organized around:

- Cells and Molecular Biology
- Genetics
- Biodiversity

Cells and Molecular Biology

Big Idea:	**Biotechnology utilizes living organisms and their parts; this requires an understanding of the various types, structures, functions and organization of cells.**	
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
Organisms can be either unicellular or multicellular. Plant and animal cells are made up of many different types of structures, including the nucleus, cell membrane, vacuoles, mitochondria, endoplasmic reticulum, ribosomes, Golgi apparatus and cytoplasm. Each organelle has a specific role in a cell. Cell division is important for growth (i.e., generating new tissues and organs), cellular repair and reproduction.	Specialized cells are organized into tissues and organs in multicellular organisms. Significant scientific discoveries have built our understanding of cellular structure (e.g., Schleiden and Schwann, Porter, etc.). Sexual and asexual reproduction have many similarities as well as many differences in their processes. Methods of asexual reproduction include binary fission, fragmentation, budding, vegetative reproduction and spore formation. Mitosis is a form of cell division in which a eukaryotic cell separates the chromosomes in its nucleus into two identical sets in two nuclei. Mitosis proceeds with a series of phases. Reproductive technologies based on cell division include cloning, artificial insemination and *in vitro* fertilization.	Prokaryotic cells and eukaryotic cells each have unique cellular structures and cellular processes. Technologies that were developed based on knowledge of cellular structure include toxicological testing, cell transplantation, etc. Many different cell components, such as plasmids, restriction enzymes, recombinant DNA and vectors are used in biotechnology. Meiosis is a form of cell division that produces reproductive cells in sexually reproducing organisms. Meiosis proceeds as a series of phases. Knowledge of cell division or development of nanotechnology can be applied to the regulation of cancerous growth in plants or animals. Technologies that were developed based on cell division include stem cell research, cancer treatment, therapeutic cloning, reproductive cloning, etc.

Big Idea:	**Biomolecules are the basis of many biotechnology products and applications, requiring an understanding of cellular processes at a molecular level.**	
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
Smaller molecules move easily through a selectively permeable cell membrane while larger molecules, like proteins, cannot. Molecules move into and out of cells through the processes of diffusion and osmosis. Elements and molecules commonly found in organisms include hydrogen, oxygen, carbon, water, etc. Proteins are a fundamental component of cells and help organisms function (e.g., digest food, fight infections, etc.).	Cells of unicellular and multicellular organisms produce thousands of different molecules. The cell membrane consists of a wide variety of molecules, primarily proteins and lipids. The phospholipid bilayer of the cell membrane protects the cell, provides structural support and controls the flow of molecules in and out of the cell. Important biochemical molecules include proteins, lipids and nucleic acid. Enzymes are proteins that catalyze biochemical reactions.	Cell membranes regulate movement of molecules into and out of cells. Regulating this movement is important for managing cell processes and maintaining homeostasis (i.e., passive transport, active transport and endo/exocytosis). Only specific types of molecules are transported between cells and capillaries (i.e., carbon dioxide, oxygen, hormones, nutrients, nitrogenous wastes). DNA consists of two long polymers of nucleotides, with backbones made of sugars and phosphate groups joined by ester bonds. Significant scientific discoveries have built our understanding of the structure and function of the DNA molecule (e.g., Watson and Crick, Matthew Meselson and Franklin Stahl, etc.). Knowledge of enzymes can be applied to technologies involving biofuels and genetic engineering.

Genetics

Big Idea:	**Cells, tissues and organisms derive their physical characteristics and function through the expression of genes to functional molecular products. The molecules and processes involved in gene expression have important applications in biotechnology.**	
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
Chromosomes are found inside the nucleus of plant and animal cells. Thousands of different genes are located on these chromosomes. Every organism has a genome that contains all of the biological information for that organism (i.e., humans have thousands of different genes located on these chromosomes, and taken together all these genes make up the human genome). Some human diseases are a result of genetic mutations.	The nucleus of a cell contains genetic information and determines cellular processes. A chromosome is a single piece of coiled DNA containing many genes. A gene is a stretch of DNA that codes for a type of protein or an RNA chain that has a function in an organism. Significant scientific discoveries have built our understanding of genes and chromosomes (e.g., work by Gregor Mendel, Thomas Hunt Morgan, Walter Fiers, etc.). Genetic problems can arise from errors in DNA structure, replication and gene expression.	DNA is transcribed into sequences of bases in RNA molecules and is finally translated into sequences of amino acids in proteins. Restriction enzymes cut DNA molecules into smaller fragments and ligases reassemble them. The process of protein synthesis utilizes mRNA, tRNA, amino acids and ribosomes. rDNA molecules can be transferred into cells to create modified organisms. Regulatory proteins play a role in the control of gene expression in both eukaryotes and prokaryotes. Many factors affect the regulation of gene expression. Techniques and technologies used to diagnose early genetic problems in humans include amniocentesis, chorionic villus sampling, maternal serum screens, etc.

Big Idea:	**The concepts and mechanisms of genetic propagation and heredity play an important role in numerous biotechnology products, processes and applications.**	
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
The passing of traits to offspring is called heredity. Some traits are inherited while others are not; knowing the difference is important. Many varieties of cultivated plants and domestic animals have resulted from selective breeding for particular traits.	For offspring to resemble their parents there must be a reliable way to transfer information from one generation to the next. Biological traits are controlled by genes located on the chromosomes found in every cell. Humans have developed technologies to modify (i.e., insert or delete) genes (e.g., genetically modified crops, pharmaceutical drugs, gene tagging, etc.). Significant scientific discoveries have built our understanding of genetics (e.g., Mendel's experiments, Human Genome Project, advances in microscopy and molecular biology, genetic engineering, cloning, etc.).	DNA, genes, chromosomes, alleles, mitosis and meiosis all have a role in the transmission of hereditary characteristics from generation to generation. Genetic disorders can be caused by chromosomal abnormalities or other genetic mutations. Ethical issues may arise as a result of genetic testing for these diseases. Genetic engineering requires knowledge of DNA as well as familiarity with genetic engineering tools and techniques (e.g., restriction enzymes, recombinant DNA, DNA amplification, bacterial vectors, viral vectors, Polymerase Chain Reaction, gel electrophoresis, DNA sequencing, etc.).

Big Idea:	**The Human Genome Project has been a catalyst for the integrated and holistic study of sets of molecules (e.g., DNA, proteins, metabolites, etc.), collectively called "omics." These related areas of research have the potential to revolutionize the diagnosis and treatment of disease.**	
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
Organisms exist in a dynamic relationship with the natural environment. Genes interact with their environment.	Some characteristics are influenced by both heredity and the environment. Personal lifestyle and environmental factors can influence protection and/or control systems. The Human Genome Project and its findings have had a profound impact on our understanding of biological processes.	"Omics" research areas inform our understanding of complex biological processes and provide comprehensive analysis of living organisms and their interactions with their environments. Genomic and proteomic technologies provide potential risks (e.g., privacy, financial, ethical, etc.) and benefits (e.g., knowledge of predisposition to disease, analysis, prevention and treatment of disease, etc.) to society. The Human Genome project and other genome sequencing projects have created potential medical and ethical implications for society. Genomics is the study of all of the genes in an organism and the interactions among them and their environment, whereas proteomics examines all of the proteins in a given cell or organism. Both fields are important to the diagnosing and treatment of diseases. Current studies in molecular biology, genomics and proteomics support the evidence for biological variation. Computational biology and bioinformatics are essential in biotechnology and help make sense of the massive amounts of data gathered (e.g., in genomic studies including annotating genomes, predicting and analyzing genetic patterns and protein sequences and creating algorithms for diagnostics, etc.).

Biodiversity

Big Idea: Biological variation exists at all levels, from micro to macro (e.g., molecules to populations).		
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
There are many different types of organisms on Earth; this variation is known as biological diversity. Each organism has unique needs and tolerances for growing and survival conditions.	Biological classification systems take into account the millions of different kinds of individual organisms that inhabit the Earth at any one time. Organisms vary both within species (i.e., intraspecies) and among species (i.e., interspecies). Variation enables species to survive under changing environmental conditions. Microorganisms (e.g., bacteria, viruses, yeast, etc.) are extremely variable, and can have both beneficial (e.g., digestion, composting, vaccine production, etc.) and harmful (e.g., diseases, food spoilage, etc.) effects.	Modern techniques used for classification of organisms include DNA/RNA comparisons, molecular clocks, radioactive dating, structural information, embryology, cellular structure, behaviour, etc. These methods are significantly different from those utilized by early scientists such as Aristotle or Linnaeus. Species diversity and genetic diversity are important for maintaining viable ecosystems. Biological variation can occur through both artificial and natural evolutionary mechanisms (e.g., natural selection, artificial selection, genetic mutations, rDNA, etc.). The use of microorganisms in biotechnology can have ethical impacts on the environment and society.

Big Idea:	**Humans have a long history of affecting biodiversity. This continues today with the application of advanced biological knowledge and modern technologies.**	
Emerging Understandings	**Developing Understandings**	**Advanced Understandings**
Humans are one part of a complex system of organisms. Humans can impact other organisms. Humans have the ability to affect reproduction and genetic traits in other organisms. Humans have introduced, and continue to introduce, organisms into ecosystems for specific purposes.	A genetically modified organism (GMO) is an organism whose genetic material has been altered using genetic engineering techniques. Humans affect biodiversity through selective breeding. Cloning organisms can have biological, social, ethical and environmental risks and benefits.	Genetically modified plants and animals can have biological, social, ethical and environmental risks and benefits. Reproductive technologies (e.g., cloning, recombinant DNA, etc.) can impact the genetic diversity of a species (e.g., farm animals, crops, etc.). Genetic manipulations at the DNA level are challenging long-held views of what is considered to be plant and animal. Transgenic organisms are organisms which have been modified with genetic material from other species.

Part Five: Big Ideas, Understandings and Learning Suggestions

Interactions: Emerging Understandings

The Business of Biotechnology

Big Idea: **Companies in various biotechnology industries participate in processes or parts of processes to develop a diverse range of products, tools and services.**

Emerging Understandings	Key Questions	Learning Suggestions
Biotechnology products and tools are based on scientific knowledge related to organisms' products or their parts. Criteria are necessary for assessing the feasibility of taking ideas through an extensive process to make functional products. Biotechnology companies employ a wide range of skilled workers in diverse careers. Human resources is an area that focuses on processes and activities related to employees and employers. Biotechnology products and services raise ethical considerations.	What is biotechnology? Can every idea become a functional product? What types of careers are available in biotechnology? What pathways (courses) are needed for the different careers in biotechnology? Why are there so many ethical issues in biotechnology?	Write down your notion of biotechnology in a journal and continue to add and revise it as your understanding of it grows. Identify an idea or solution based on a want or need and take it through a design process to a final product or invention. Reflect on the process and the role of using criteria to determine if the resulting product was successful. Make a career portfolio of different types of careers that are needed in biotechnology industries. Research which courses are important to the different types of careers. Brainstorm a list of issues related to a biotechnology topic (e.g., genetically modified plants or animals, DNA fingerprinting, etc.). Identify what ethical questions these issues raise.

Big Idea: Intellectual property (IP) protection plays a central role in biotechnology innovation.

Emerging Understandings	Key Questions	Learning Suggestions
Intellectual property is the result of ongoing innovations and creativity. Intellectual property can be a product, a composition, a piece of equipment, a process or an improvement on any of these. Intellectual property is based on the legal right of the owners to exclude others from using the "property."	What is intellectual property? Why is protecting intellectual property rights important? What are the consequences if we do not have intellectual property rights?	Identify ways in which intellectual properties rights are violated daily by many people (e.g., downloading, without permission of the owner, music, software, movies or television shows from the Internet, etc.). Debate the fairness of protecting the creative process through intellectual property rights against individual rights of choice if the "property" can be easily accessible through other means.

Big Idea: Biotechnology discoveries, processes, products and services have ethical implications.

Emerging Understandings	Key Questions	Learning Suggestions
Ethical questions are different from research questions and legal questions. Ethical considerations include respect for people, minimizing harm while maximizing benefit and ensuring fairness. People's different beliefs, values and life experiences can shape their position about ethical issues. Ethical considerations include the procurement, use and care of animals involved in the research, development and production of biotechnology processes, products and services.	What is ethics and how is it different from law or values? What thinking processes would you use to resolve an ethical issue? Is there a "right" answer or solution to resolving an ethical issue? How can ethical issues have any resolution when everyone has their own beliefs and values?	Differentiate between ethical, scientific, legal and personal-choice/preference questions. Identify the questions that arise from a biotechnology-related issue and classify which are ethical, scientific, legal or personal-choice/preference questions. Use reasoning skills to develop a point of view on an ethical issue related to biotechnology (Teacher support resource: http://science.education.nih.gov/supplements/nih9/bioethics/guide/default.htm (accessed April 9, 2010). Show respect for the reasoned and persuasive arguments of others when discussing ethical issues. Select and care for a suitable classroom animal following established guidelines including ethical consideration for their care and welfare.

Biotechnology and the Public

Big Idea:	**Communication about advances in biotechnology and biosciences research is important for public awareness and understanding about related issues that impact their lives.**

Emerging Understandings	Key Questions	Learning Suggestions
Different means of communication may be better suited to one audience over another depending on the purpose of the communication (e.g., scientific research journals for scientists, town hall meetings for the general public, etc.). Surveys are often used as a means of gathering information about the public's perceptions and attitudes towards biotechnology research and industries. The media is a major source of communication to the general public.	Why is it important to know who your audience is when communicating a message? What is a survey and what are some of the ways it is used? Does everyone have to participate in a survey if they are asked to? What do we mean by media? Is media bias-free?	Develop a communication plan for an information item around a biotechnology innovation. Include who is/are the target audience(s); what communication means is most suitable for the chosen audience(s); and the design and content of the information. Conduct a survey about the perceptions that your peers, parents and family friends have about a biotechnology innovation and analyze the results. Analyze a media source (e.g., newspaper, popular science journal, magazine, electronic media, etc.) reporting about an issue related to biotechnology for authority, bias, accuracy and validity of information.

Big Idea:	**The results of biotechnology innovations and biosciences research range from those that are highly controversial to those that are well accepted and considered essential to our lives.**

Emerging Understandings	Key Questions	Learning Suggestions
Many products commonly used on a daily basis are due to biotechnology innovations and biosciences research (e.g., living cells are used to make beer, wine, bread, yogurt and cheese; enzymes are used in textiles to replace harsh chemicals in manufacturing processes; etc.). Understanding about the structure and function of cells and tissues has brought about improvements in human health, food production and nutrition.	Have you used or eaten something today that was developed using biotechnology innovations? How have advances in biotechnology made your life different from your parents? From your grandparents?	Identify which items that use biotechnology innovations you (or your family) consume daily, weekly and monthly. Describe how your life would be different if these products did not exist. Compare the pros and cons of how advances in biotechnology related to health care, food production or nutrition have made choices in your life different from those of your parents or grandparents (e.g., different versions of penicillin like amoxicillin are now possible due to our understanding of molecules in cells, etc.).

Biotechnology and the Environment

Big Idea:	**Biotechnology industries and biosciences research contribute to efficient and environmentally responsible use of natural, human and economic resources.**

Emerging Understandings	Key Questions	Learning Suggestions
Biotechnology applications are found in environmental sectors (e.g., bioremediation, phytoremediation, managing soil structure and fertility, etc.). Bio-based fuels are being investigated as a source of alternative energy. Biotechnology products, technologies and applications can impact the environment depending on human wants and needs (e.g., use of oil eating bacteria to clean up oil spills vs. cost and effort involved, etc.).	What resource industries currently use biotechnology innovations? What are biofuels? How feasible are biofuels as an alternative source of energy, in the short term and in the long-term? What are the pros and cons of using biotechnology innovations? How does analyzing the risks and benefits assist in resolving ethical considerations for biotechnology solutions to environmental issues?	Create a chart of resource industries and the biotechnology innovations that they are currently using, and those that are still experimental. Research use of biofuels in different transportation sectors. Compare the pros and cons of biofuels to other fuel sources, including fossil fuels, in those sectors. Research the pros and cons of various alternative energy sources, including biofuels. Use an ethical reasoning process to analyze ethical issues related to using biotechnology solutions for sustainability concerns: • What is the ethical question inherent in the issue?[4] • What are the relevant facts? What is the evidence to support these facts? Are there disagreements? What facts don't you know about the issue and how will you find out? • Who or what could be affected by the way the issue gets resolved? • Does your decision about the issue account for respect for others, minimizing risks while maximizing benefits, include fairness ensuring benefits, resources and costs are shared.

[4] Reasoning process adapted from Exploring Bioethics developed by the National Institutes of Health in collaboration with the Department of Bioethics at the NIH Clinical Center. Resource accessible at: http://science.education.nih.gov/supplements/nih9/bioethics/default.htm (accessed April 9, 2010).

Variation: Emerging Understandings

Cells and Molecular Biology

Big Idea:	**Biotechnology utilizes living organisms and their parts; this requires an understanding of the various types, structures, functions and organization of cells.**

Emerging Understandings	Key Questions	Learning Suggestions
Organisms can be either unicellular or multicellular. Plant and animal cells are made up of many different types of structures, including the nucleus, cell membrane, vacuoles, mitochondria, endoplasmic reticulum, ribosomes, Golgi apparatus and cytoplasm. Each organelle has a specific role in a cell. Cell division is important for growth (i.e., generating new tissues and organs), cellular repair and reproduction.	How can organisms and their parts be considered the "raw material" of biotechnology? What are the similarities and differences between unicellular and multicellular organisms? How do organelles work together within a cell? Why is cell division important? Why do cells in a multicellular organism continue to reproduce even after the organism is fully grown?	Describe how our understandings of the structure and function of cells has enabled us to create products from organisms or their parts (e.g., medical advances are based on a better understanding of how cells, tissues and organs function, etc.). Differentiate between unicellular and multicellular organisms. Construct a chart summarizing the similarities and differences of animal and plant structures (i.e., nucleus, cell membrane, cell wall, chloroplasts, vacuoles, mitochondria, endoplasmic reticulum, ribosomes, Golgi apparatus and cytoplasm). Use a microscope correctly and safely to observe and accurately draw and identify cell structures in plants and animals. Create a simulation of how organelles work together in a cell. Explain the importance of cell division for growth (i.e., generating new tissues and organs), cellular repair and reproduction.

Big Idea:	**Biomolecules are the basis of many biotechnology products and applications, requiring an understanding of cellular processes at a molecular level.**

Emerging Understandings	Key Questions	Learning Suggestions
Smaller molecules move easily through a selectively permeable cell membrane while larger molecules, like proteins, cannot. Molecules move into and out of cells through the processes of diffusion and osmosis. Elements and molecules commonly found in organisms include hydrogen, oxygen, carbon, water, etc. Proteins are a fundamental component of cells and help organisms function (e.g., digest food, fight infections, etc.).	What is the role of the cell membrane? How are osmosis and diffusion different? How are they similar? How is an understanding of osmosis and diffusion important to biotechnology? What elements and molecules diffuse freely into and out of cells? What are proteins? What is the role of proteins in cells?	Investigate which types of molecules can move easily through a selectively permeable cell membrane and which cannot. Conduct an experiment about osmosis and diffusion using plant and animal cells. Investigate an application in biotechnology based on diffusion (e.g., drug patches: drug particles contained in high concentration diffuse to the low concentration in the body through the skin into the bloodstream, etc.). Make a comparison chart of the molecules commonly found in organisms and their elements. View animations about proteins online (e.g., http://learn.genetics.utah.edu/content/begin/tour/) (accessed April 9, 2010), etc.). Create a chart of types of proteins found in cells and their functions in cells (e.g., enzymes, structural proteins, etc.).

Genetics

Big Idea:	**Cells, tissues and organisms derive their physical characteristics and function through the expression of genes to functional molecular products. The molecules and processes involved in gene expression have important applications in biotechnology.**

Emerging Understandings	Key Questions	Learning Suggestions
Chromosomes are found inside the nucleus of plant and animal cells. Thousands of different genes are located on these chromosomes. Every organism has a genome that contains all of the biological information for that organism (i.e., humans have thousands of different genes located on these chromosomes, and taken together all these genes make up the human genome). Some human diseases are a result of genetic mutations.	Where do you find genetic material in a cell? How do genes relate to understanding an organisms genome? How can the study of genes help us understand human diseases?	Create a model of chromosomes using modelling clay. View animations about chromosomes and genes on the Internet (e.g., http://learn.genetics.utah.edu/content/begin/tour/ (accessed April 9, 2010), etc.). Create a 3-dimensional model of a DNA molecule. Extract DNA from plant or animal tissues (e.g., banana, onion, liver, kiwi, etc.) Research a disease caused by a genetic mutation; include if any treatments or therapies are available.

Big Idea:	**The concepts and mechanisms of genetic propagation and heredity play an important role in numerous biotechnology products, processes and applications.**	
Emerging Understandings	**Key Questions**	**Learning Suggestions**
The passing of traits to offspring is called heredity. Some traits are inherited while others are not; knowing the difference is important. Many varieties of cultivated plants and domestic animals have resulted from selective breeding for particular traits.	What is the difference between inherited traits and learned characteristics? How have humans experimented with genetic manipulations in plants and animals?	Create a T-Chart listing human traits that are inherited and those that are not. Create a list of agricultural crops that are a direct result of selective breeding (e.g., rust-resistant wheat, sweet full kernel corn, canola, etc.). Describe examples of selective breeding used domestically (e.g., selective breeding of pets for desirable traits, show plants at horticultural shows and agriculture fairs, etc.).
Big Idea:	**The Human Genome Project has been a catalyst for the integrated and holistic study of sets of molecules (e.g., DNA, proteins, metabolites, etc.), collectively called "omics." These related areas of research have the potential to revolutionize the diagnosis and treatment of disease.**	
Emerging Understandings	**Key Questions**	**Learning Suggestions**
Organisms exist in a dynamic relationship with the natural environment. Genes interact with their environment.	How do organisms interact with the natural environment? What do organisms need from their environment to survive? What other environmental factors can influence a cell's genetic information?	Differentiate between key items that cells need from their environment in order to survive and other items they are exposed to that could influence a cell's genetic information. Describe behaviours in which humans can impact their bodies. Create a list of factors that may lead to changes in a cell's genetic information and categorize them according to mutations caused by nature, and mutations caused by humans interacting with their environment.

Biodiversity

Big Idea:	Biological variation exists at all levels, from micro to macro (e.g., molecules to populations).

Emerging Understandings	Key Questions	Learning Suggestions
There are many different types of organisms on Earth; this variation is known as biological diversity. Each organism has unique needs and tolerances for growing and survival conditions.	What is biological diversity? Where is a given organism best suited to grow and survive? Why would living elsewhere be detrimental?	Research traditional methods for tracking biological diversity and explain how biological classification takes into account the diversity of life on Earth. Describe examples of variation of characteristics within a species, and identify examples of both discrete and continuous variation. Investigate and interpret variations in needs of different organisms and their tolerance for different growing and survival conditions.

Big Idea:	Humans have a long history of affecting biodiversity. This continues today with the application of advanced biological knowledge and modern technologies.

Emerging Understandings	Key Questions	Learning Suggestions
Humans are one part of a complex system of organisms. Humans can impact other organisms. Humans have the ability to affect reproduction and genetic traits in other organisms. Humans have introduced, and continue to introduce, organisms into ecosystems for specific purposes.	How do humans affect biodiversity? How can humans affect reproduction and genetic traits in other organisms? What organisms have humans introduced into ecosystems? What is the purpose of introducing organisms into ecosystems?	List examples of instances when humans have affected reproduction and genetic traits in other organisms (e.g., plant breeding, fish stocks, etc.). Describe instances in which humans have introduced organisms into ecosystems for specific purposes (e.g., oil-eating bacteria, rust-resistant wheat, canola, drought-resistant plants, high-yield crop plants and animal breeds, etc.).

Interactions: Developing Understandings

The Business of Biotechnology

Big Idea:	**Companies in various biotechnology industries participate in processes or parts of processes to develop a diverse range of products, tools and services.**

Developing Understandings	Key Questions	Learning Suggestions
It takes many years of discovery, research, exploratory development and full development before an idea becomes a biotechnology product that is approved for use. Companies spend millions (and sometimes billions) of dollars in research and development when producing a new product for the marketplace. Financial factors such as risk assessment and return on investment are major considerations to bring a product to the marketplace. The development of a product is integrated with compliance to regulatory requirements. Regulations ensure the safety and efficacy of biotechnology products. Human resources involves acquiring and sustaining a dedicated workforce.	How is a biotechnology product developed? What are regulations and why do we have them? What regulations does Canada have related to biotechnology? What is the Krever Inquiry and what were some of its findings? How does human resources contribute to a company's productivity, efficiency, motivation and effectiveness?	Research what stages are involved in the development of a biotechnology product (i.e., product identification, research and development, small-scale manufacturing, testing for safety and efficacy, manufacturing, sales and marketing) and compare your research with others and generalize stages that are common. Describe how regulations provide a legal framework to monitor the activities of a business. Identify the Canadian regulations related to biotechnology (e.g. health, environmental, agricultural, industrial, etc.). Describe how complying with regulations are part of the financial costs of operating a business (e.g., administrative, legal, monitoring, etc.). Conduct research about *The Commission of Inquiry on the Blood Systems in Canada* (Krever Inquiry) and report on the purpose of the inquiry, its findings, recommendations and results.

Big Idea:	**Intellectual property (IP) protection plays a central role in biotechnology innovation.**	
Developing Understandings	**Key Questions**	**Learning Suggestions**
There are different types of intellectual property rights, including patents, trademarks, copyrights, industrial designs and integrated circuit topography. Many intellectual property rights are modifications of existing products and processes. Owning the rights to organisms' products, parts of organisms or processes involving organisms and their parts raises ethical issues.	What are the different types of intellectual property rights in Canada? Why are trademarks important to the branding of a business or organization? What ethical considerations arise when organisms or parts of organisms are owned?	Create a chart listing the five types of intellectual property, a description of each and examples that relate to biotechnology industries. Research different trademarks of biotechnology industries. Identify those you recognize and in what circumstances you have seen them. Describe the value to a business of having a trademark that is instantly recognizable to consumers. Form a point of view based on reasoning skills as to whether patents should include owning the rights to organisms or parts of organisms. (Teacher resource support: http://science.education.nih.gov/supplements/nih9/bioethics/guide/default.htm (accessed April 9, 2010)).

Big Idea: Biotechnology discoveries, processes, products and services have ethical implications.

Developing Understandings	Key Questions	Learning Suggestions
Ethical considerations should be examined from multiple perspectives so that solutions are thoroughly considered and are morally grounded, fair, just and reasonable (e.g., research ethics review boards, guidelines for the care and use of experimental animals, farm animals, fish and wildlife, etc.). Bioethics is a multidisciplinary branch of ethics related to life sciences. Bioethicists can be involved in research programs, clinical committees, law practices, regulatory reviews and policy-making.	How can ethical issues be discussed in a reasoned and fair way when everyone has their own viewpoints? What is bioethics? What are bioethicists? What do bioethicists do? How does one become a bioethicist?	Choose an issue related to biotechnology (e.g., all children must provide proof of immunization before they can attend a school, use of animals in research, etc.). Brainstorm a list of people/groups affected by the issue. Develop a consequence map illustrating how people/groups related to this issue are affected. Discuss ethical considerations and suggest a respectful and reasoned action. (Teacher resource support: http://science.education.nih.gov/supplements/nih9/bioethics/guide/default.htm (accessed April 9, 2010)). Differentiate between ethics and bioethics. Research profiles of different bioethicists on the Internet. Summarize what they do and how they got to their positions.

Biotechnology and the Public

Big Idea: **Communication about advances in biotechnology and biosciences research is important for public awareness and understanding about related issues that impact their lives.**

Developing Understandings	Key Questions	Learning Suggestions
Different stakeholders shape public perceptions about biotechnology (e.g., journalists, industry public relations and marketing managers, scientists, special interest groups, health care providers, politicians, etc.). Communication technologies are influencing ways people access and share information (e.g., blogs, websites, RSS feeds, Twitter, etc.). Mass media can impact and influence public information about biotechnology issues and ideas.	How do different stakeholders shape public perceptions about biotechnology? What is meant by communication technologies? How are new forms of communication technologies shaping how we communicate with each other? How can information be assessed as to its accuracy, currency, reliability and bias?	Identify different stakeholders who can shape public perceptions of biotechnology. Identify a special interest group that is opposed to using animals for research purposes. Investigate their position and their tactics to communicate their message as well as the counterarguments and counter-tactics used by those who disagree with their position. Identify different forms of communication using the Internet (e.g., e-zines, blogs, Twitter, comments, articles, etc.). Choose one and search how a topic related to biotechnology is represented on the Internet. Assess the information according to accuracy, currency, reliability and bias.

Big Idea:	**The results of biotechnology innovations and biosciences research range from those that are highly controversial to those that are well accepted and considered essential to our lives.**

Developing Understandings	Key Questions	Learning Suggestions
Some biotechnology products and services are highly controversial (e.g., genetically-modified plants, cloning, using stem cells from embryos, etc.). Some biotechnology products and services are well accepted and considered essential (e.g., production of insulin through genetically-modified bacteria, bioremediation, harvesting and processing forest fibre, etc.).	What makes an issue controversial in biotechnology? Why are some biotechnology innovations more controversial than others?	Develop a consequence map for a topic in biotechnology (e.g., bioremediation, genetically modified crops for increase global food yields, biofuels, gene therapy, etc.). Provide primary, secondary and tertiary consequences. Analyze the information and predict whether or when the products related to the topic may become controversial or accepted as essential. Identify the benefits and costs associated with applications of biotechnology in agriculture and food production.

Biotechnology and the Environment

Big Idea: **Biotechnology industries and biosciences research contribute to efficient and environmentally responsible use of natural, human and economic resources.**

Developing Understandings	Key Questions	Learning Suggestions
Biotechnology industries contribute to finding solutions for the sustainability of terrestrial and aquatic ecosystems (e.g., biopesticides, treatment of waste water effluent, use of DNA fingerprinting to manage wild fish stocks, etc.). New biotechnology products, technologies and applications have both risks and benefits to sustainability. Genetic modification of plants and animals is used by agricultural biotechnology firms to combat the growing challenges presented by drought and malnutrition, and to decrease the environmental impact of agriculture.	How does biotechnology affect sustainability? What are the environmental risks and benefits of using biotechnology innovations? How have agriculture industries used biotechnology innovations? What are some of the ethical issues that arise when using biotechnology innovations in agriculture and food production?	Describe how DNA fingerprinting is helping food inspectors to detect deception in the food industry in how food is marketed and priced. Research the biotechnology applications involved in harvesting and processing the forest fibre resource. Describe biotechnology innovations that do and can contribute to local and global issues in resource management practices and management plans (e.g., forestry: understanding the pine genome to ensure healthier forests and sustainable forestry practices, species protection, pest management, forest regeneration, pulp and paper processing; etc.). Research the benefits of using microbes to clean up pollution, to manufacture foods, to manufacture chemicals and in microbial mining. Debate the risks and benefits of using genetically modified animals and plants that can reach the market and cost less to feed vs. unknown consequences for the ecosystem.

Variation: Developing Understandings

Cells and Molecular Biology

Big Idea:	**Biotechnology utilizes living organisms and their parts; this requires an understanding of the various types, structures, functions and organization of cells.**

Developing Understandings	Key Questions	Learning Suggestions
Specialized cells are organized into tissues and organs in multicellular organisms. Significant scientific discoveries have built our understanding of cellular structure (e.g., Schleiden and Schwann, Porter, etc.). Sexual and asexual reproduction have many similarities as well as many differences in their processes. Methods of asexual reproduction include binary fission, fragmentation, budding, vegetative reproduction and spore formation. Mitosis is a form of cell division in which a eukaryotic cell separates the chromosomes in its nucleus into two identical sets in two nuclei. Mitosis proceeds with a series of phases. Reproductive technologies based on cell division include cloning, artificial insemination and *in vitro* fertilization.	What are the advantages of cell specialization for an organism? Why are specialized cells dependent on other specialized cells? How has our understanding of cellular structure changed over time? What is the significance of the cell nucleus? How is asexual reproduction used in agriculture? What is mitosis? What are reproductive technologies?	Explain the links between specialized cells and their organization into tissues, organs and systems in multicellular organisms (i.e., plants and animals). Research significant scientific discoveries that have built our understanding of cellular processes, including timeline, advances in technology (e.g., microscopes, etc.), individual and collaborative contributions and any competitive environment. Compare and contrast asexual and sexual reproduction. Describe how grafting is used in agriculture, including the techniques and advantages. Build an interactive model of mitosis illustrating the dynamic continuous process of cell division. View an animation of mitosis on the Internet (e.g., http://www.cellsalive.com/mitosis.htm (accessed April 9, 2010), etc.). Investigate different examples of reproductive technologies and identify the pros and cons of each.

Big Idea:	**Biomolecules are the basis of many biotechnology products and applications, requiring an understanding of cellular processes at a molecular level.**

Developing Understandings	Key Questions	Learning Suggestions
Cells of unicellular and multicellular organisms produce thousands of different molecules. The cell membrane consists of a wide variety of molecules, primarily proteins and lipids. The phospholipid bilayer of the cell membrane protects the cell, provides structural support and controls the flow of molecules in and out of the cell. Important biochemical molecules include proteins, lipids and nucleic acid. Enzymes are proteins that catalyze biochemical reactions.	What is the structure of the cell membrane? What are some important biochemical molecules in cells? What is the purpose of enzymes?	Describe the molecular structure of cell membranes. Identify and describe the structure of important biochemical molecules, including carbohydrates, proteins and lipids and nucleic acids, and explain their function within cells. Create and organize a list of common biochemical enzymes, include a diagram of their chemical structure. Conduct a lab experiment illustrating how enzymes work. Use the Internet to view animations about how enzymes work (e.g., http://www.tvdsb.on.ca/westmin/science/sbi3a1/digest/enzymes.htm) (accessed April 9, 2010), etc.).

Genetics

Big Idea:	**Cells, tissues and organisms derive their physical characteristics and function through the expression of genes to functional molecular products. The molecules and processes involved in gene expression have important applications in biotechnology.**

Developing Understandings	Key Questions	Learning Suggestions
The nucleus of a cell contains genetic information and determines cellular processes. A chromosome is a single piece of coiled DNA containing many genes. A gene is a stretch of DNA that codes for a type of protein or an RNA chain that has a function in an organism. Significant scientific discoveries have built our understanding of genes and chromosomes (e.g., work by Gregor Mendel, Thomas Hunt Morgan, Walter Fiers, etc.). Genetic problems can arise from errors in DNA structure, replication and gene expression.	How are chromosomes, genes and DNA interconnected? What is the function of DNA? How can genes and chromosomes develop errors?	Explain the relationship between chromosomes, genes and DNA. Outline significant scientific contributions/discoveries that lead to our understanding of genes and chromosomes including timeline, individual and collaborative contributions and competitive environment. Research a disease or irregularity that is a result of an error in gene replication or expression; include whether advances in biotechnology have led to or may lead to treatment.

Big Idea:	**The concepts and mechanisms of genetic propagation and heredity play an important role in numerous biotechnology products, processes and applications.**

Developing Understandings	Key Questions	Learning Suggestions
For offspring to resemble their parents there must be a reliable way to transfer information from one generation to the next. Biological traits are controlled by genes located on the chromosomes found in every cell. Humans have developed technologies to modify (i.e., insert or delete) genes (e.g., genetically modified crops, pharmaceutical drugs, gene tagging, etc.). Significant scientific discoveries have built our understanding of genetics (e.g., Mendel's experiments, Human Genome Project, advances in microscopy and molecular biology, genetic engineering, cloning, etc.).	How is genetic information transferred from one generation to the next? How do humans modify genes? Why do humans modify genes?	Investigate the transmission of characteristics from parents to offspring, and identify examples of characteristics in offspring. Investigate own family history looking for examples of shared characteristics. Describe a technology used by humans to modify genes. Research a genetically modified crop plant; include any controversies related its use and analyze the arguments around the controversies. Outline significant scientific contributions/discoveries that led to our understanding of genetics, including timeline, individual contributions, multidisciplinary collaboration and competitive environment.

Big Idea:	**The Human Genome Project has been a catalyst for the integrated and holistic study of sets of molecules (e.g., DNA, proteins, metabolites, etc.), collectively called "omics." These related areas of research have the potential to revolutionize the diagnosis and treatment of disease.**

Developing Understandings	Key Questions	Learning Suggestions
Some characteristics are influenced by both heredity and the environment. Personal lifestyle and environmental factors can influence protection and/or control systems. The Human Genome Project and its findings have had a profound impact on our understanding of biological processes.	Which of an organism's characteristics are influenced by both heredity and the environment? How can personal lifestyle choices affect protection and/or control systems? What is the significant of the Human Genome Project?	Identify characteristics for which heredity and environment may both have a role in determining. Describe how personal lifestyle and environmental factors can influence protection and/or control systems (e.g., impact of drugs, neurotoxins, anabolic steroids, mercury, cadmium, lead, hormones, sleep, diet, etc.). Research and explain the importance of the Human Genome Project, why it was initiated, and describe the major findings of the project. (Online education resource: http://www.genome.gov/25019879 (accessed April 9, 2010)).

Biodiversity

Big Idea: Biological variation exists at all levels, from micro to macro (e.g., molecules to populations).

Developing Understandings	Key Questions	Learning Suggestions
Biological classification systems take into account the millions of different kinds of individual organisms that inhabit the Earth at any one time. Organisms vary both within species (i.e., intraspecies) and among species (i.e., interspecies). Variation enables species to survive under changing environmental conditions. Microorganisms (e.g., bacteria, viruses, yeast, etc.) are extremely variable, and can have both beneficial (e.g., digestion, composting, vaccine production, etc.) and harmful (e.g., diseases, food spoilage, etc.) effects.	How is biotechnology contributing to the classification of species? How do species vary within species (i.e., intraspecies)? How do species vary among species (i.e., interspecies)? How can variation help organisms to survive under changing environmental conditions? What are microorganisms and why are they so variable? How can microorganisms be both beneficial and harmful?	Research the Barcode of Life initiative for species identification. Compare it with commonly used classification systems (e.g., Linnaean system, cladistics, etc.). Describe variation in living things, including examples of variation among species and within species. Identify the role of variation in species survival under changing environmental conditions. Identify beneficial and harmful roles of microorganisms (e.g., beneficial: aids in digestion, composting, food and vaccine production, etc.; harmful: causes disease, food spoilage, etc.). Assess the effects of microorganisms in the environment, and analyze ethical issues related to their use in biotechnology.

Big Idea:	**Humans have a long history of affecting biodiversity. This continues today with the application of advanced biological knowledge and modern technologies.**	
Developing Understandings	**Key Questions**	**Learning Suggestions**
A genetically modified organism (GMO) is an organism whose genetic material has been altered using genetic engineering techniques. Humans affect biodiversity through selective breeding. Cloning organisms can have biological, social, ethical and environmental risks and benefits.	What is a genetically modified organism (GMO)? Why does selective breeding affect biodiversity? What are the advantages and disadvantages of using cloning techniques in agriculture? What are some ethical considerations about human's having the ability to manipulate biodiversity?	Define genetically modified organism (GMO) and provide some examples of their applications (e.g., pharmaceuticals, agriculture, food production, etc.). Debate the pros and cons of producing genetically modified food from the perspectives of different sectors of society (e.g., farmers, politicians, consumers, researchers, industry, environmentalists, etc.). Examine and describe various types of selective breeding techniques (e.g., crossbreeding, hybridization, artificial insemination, super ovulation and embryo transfer, etc.). Analyze from a biological, social, ethical and environmental perspective the risks and benefits of cloning organisms.

Interactions: Advanced Understandings

The Business of Biotechnology

Big Idea: Companies in various biotechnology industries participate in processes or parts of processes to develop a diverse range of products, tools and services.

Advanced Understandings	Key Questions	Learning Suggestions
Some basic requirements for biotechnology companies are similar to other businesses, such as developing: feasibility studies; venture plans; marketing plans; financial plans; business plans; work plans; human resources strategies; investment funds; governance policies; and production costs (e.g., land/real estate, labour, etc.). There are different business models in biotechnology based on the nature of the company (e.g., products, services, therapeutics, consulting, data generation, etc.). Countries can have different regulations pertaining to biotechnology (e.g., bovine growth hormone is approved for use in dairy cattle in United States but not in Canada, etc.).	What is a business? How are companies organised and operated? What funding sources are available to businesses? What external forces influence business and management decisions? What are some different business models? How is a business model chosen? How do regulations impact on companies that want to bring their products to the global marketplace?	Compare different forms of business ownership depending on the purpose of the business. Propose a venture that involves scientific research to develop a product, and evaluate its viability (e.g., availability of start-up capital, size of target market, technological feasibility, timelines for research and development to production, etc.). Apply business principles to specific scenarios and case studies involving biotechnology. Discuss and evaluate the responsibility of government and of industry in financing biotechnology innovations in resource industries, product industries and biosciences and health industries. Identify global factors that influence business strategies (i.e., political: political change, political uncertainty, war/terrorism; economic: tax systems, monetary and fiscal policies, international regulation and bureaucracy, exchange rates; social: religious considerations, cultural issues, considerations, different worldviews, availability of jobs, training, wages; technological: access to bandwidth, processing payments, compatibility of business management technologies). Interview a regulatory specialist from a multinational company to learn how they address and stay informed about regulations in the countries in which they operate.

Big Idea: Intellectual property (IP) protection plays a central role in biotechnology innovation.

Advanced Understandings	Key Questions	Learning Suggestions
Patents help to secure the business potential of innovative ideas (e.g., competitive edge, blocking others from entering the market, trade with other companies, reputation as innovators to investors, etc.). Patents are essential for protection of marketing rights and financing. A new era of intellectual property considerations are emerging which emphasizes working cooperatively through sharing and collaboration instead of increased protection.	Should a company be able to own a patent on an organism or part of an organism (e.g., gene)? Why are patents essential to biotechnology research and industries? Is there equitable access of patented drugs and vaccines to all populations around the world?	Explain the link between competitive advantage and having patents. Discuss the risk and benefits of having companies patent organisms and genetic material (e.g., modified micro-organisms, etc.). Identify factors that obstruct access of drugs and treatments to many populations in low and middle-income countries. Investigate the legislative process required to bring changes to existing regulations or to develop new regulations that do not yet account for advances in biotechnology innovations and processes.

Big Idea: Biotechnology discoveries, processes, products and services have ethical implications.

Advanced Understandings	Key Questions	Learning Suggestions
The *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* governs research ethics protocols in Canada and the Canadian Council on Animal Care sets and maintains standards for the care and use of animals used in research, teaching and testing throughout Canada. Addressing ethical questions distinguishes between relevant and irrelevant facts and courses of action are based on critical reasoning skills. Justifications of courses of actions related to ethical considerations include both positive and negative impacts on multiple stakeholders and how they could be affected.	Why do we have protocols for research ethics involving using organisms? What are some ethical issues that arise when conducting research involving humans? How is a reasoned argument about an ethical issue in biotechnology different from an opinion? Is access to patented biotechnology innovations available equitably to all populations around the world?	Identify certain protections that are in place in Canada when conducting research involving humans, including ensuring voluntary and informed consent. Construct arguments to support a decision concerning the use of genetic engineering, using evidence and recognizing various perspectives. Assess risks in contributions of genetics research on using information to deny insurance coverage or payment of claims (predisposition). Debate whether biotechnology innovations that could have great benefits to all of humankind should be patentable. Compare and contrast human research ethics protocols with animal research ethics protocols in Canada. Debate providing reasoned arguments whether using animals in research is beneficial or harmful.

Biotechnology and the Public

Big Idea: **Communication about advances in biotechnology and biosciences research is important for public awareness and understanding about related issues that impact their lives.**

Advanced Understandings	Key Questions	Learning Suggestions
Communication about biotechnology-related issues requires accurate and current information, including the uncertainties of the research and the potential impacts on society. Communication on biotechnology-related issues must be open to society's response to the potential impacts and ethical considerations of these issues. Policymakers and politicians are influenced by how the public responds to biotechnology issues.	How does an awareness of and sensitivity towards the multiple perspectives in a pluralistic society enhance the ability to communicate effectively? How can the uncertainties of cutting-edge research and products that have not stood the test of time be communicated positive and accurately?	Discuss how multiple perspectives, including Aboriginal, shape Canada's views about biotechnology and that public debate on controversial issues is necessary in a democratic society to consider solutions for society to consider. Choose a controversial issue (e.g., Krever inquiry, etc.) related to biotechnology that evoked responses which brought about changes in the law. Describe a wide variety of strategies that may be used for changing the law.

Big Idea:	**The results of biotechnology innovations and biosciences research range from those that are highly controversial to those that are well accepted and considered essential to our lives.**

Advanced Understandings	Key Questions	Learning Suggestions
Humans have exploited and manipulated biodiversity since the Green Revolution to develop and preserve food products used for human consumption (e.g., bacteria to ferment and preserve foods, selective breeding of grain crops for higher yields and hardiness, specialized breeds of cattle for milk or meat production, etc.). Continued advances in health-related biotechnologies (e.g., nanobiotechnology, therapeutics, diagnostics, etc.) play an important role as a preventative tool in Canada's health care system and will continue to raise ethical and philosophical issues (e.g., personalized medicine, stem cell therapies, etc.).	What products of biotechnology have been accepted over time? How is biotechnology affecting our health care?	Examine the societal, economic and technological factors when tracing the development of plant and animal breeding techniques, starting with traditional practices (e.g., Aboriginal) to Mendel's work on inheritance, to the contributions of many scientists on the discovery of the molecular structure of DNA and the development of recombinant DNA technology. Investigate a current area of research in biotechnology in the health industries and determine its significance if introduced into the marketplace, as well as the ethical considerations that should be addressed (e.g., therapeutics: biological drugs that include skin grown for burn victims, personalized medicine, gene therapies, stem cell therapies; diagnostics: test kits for HIV or for diabetes that help to detect and design targeted treatments; medical devices: biosensors; and some vaccines; etc.).

Biotechnology and the Environment

Big Idea: **Biotechnology industries and biosciences research contribute to efficient and environmentally responsible use of natural, human and economic resources.**

Advanced Understandings	Key Questions	Learning Suggestions
Biotechnology innovations are one way of protecting diversity of species. Bioresources support efforts to produce renewable energy (e.g., biodiesel is a fuel source produced from plant and animal fats; new sources of fuel may be possible by turning "on" genes that regulate growth to improve yields for biofuel crops, etc.). Genome sequencing projects can lead to improvements in yield and quality of food crops, including enhanced disease and insect resistance and improved performance under drought, saline or heat-stressed conditions. The benefits achieved through biotechnology have not been equally shared by all peoples and all societies.	How can biotechnology play a role in protecting the diversity of species? How are bioresources a source of alternative renewable energy? What are the pros and cons of using bioresources as an energy source? What role can genome sequencing projects contribute to sustainability? How are the benefits of biotechnology shared globally? Should the benefits of biotechnology be shared globally?	Investigate ways in which biotechnology can play a role in protecting the diversity of species (e.g., DNA fingerprinting to manage wild fish stocks, Genebanks can play a role in the preservation of endangered species and genotypes of plants and animals, etc.). Evaluate the use of biotechnology as one way of solving problems related to sustainability (e.g., aquaculture: Genes are transferred into fish to make them grow bigger than normal, to be able to survive in waters colder than their natural habitats and to resist disease. These fish are kept in closed systems. What happens if they escape? Is this a risk worth taking against the benefits of increasing fish yields for food supplies?; etc.). Research a biotechnology innovation that offers a solution to a human problem, and examine issues related to accessibility, culture and ethics (e.g., golden rice and Vitamin A deficiency, etc.). Describe how bioresources could support efforts to produce renewable energy, improve health and minimize environmental impact; identify pros and cons regarding the impact of bioresources on the availability of food crops and the price of food. Debate why benefits of biotechnology should or should not be shared globally.

Variation: Advanced Understandings

Cells and Molecular Biology

Big idea: **Biotechnology utilizes living organisms and their parts; this requires an understanding of the various types, structures, functions and organization of cells.**

Advanced Understandings	Key Questions	Learning Suggestions
Prokaryotic cells and eukaryotic cells each have unique cellular structures and cellular processes. Technologies that were developed based on knowledge of cellular structure include toxicological testing, cell transplantation, etc. Many different cell components, such as plasmids, restriction enzymes, recombinant DNA and vectors are used in biotechnology. Meiosis is a form of cell division that produces reproductive cells in sexually reproducing organisms. Meiosis proceeds as a series of phases. Knowledge of cell division or development of nanotechnology can be applied to the regulation of cancerous growth in plants or animals. Technologies that were developed based on cell division include stem cell research, cancer treatment, therapeutic cloning, reproductive cloning, etc.	What are the similarities and differences between prokaryotic cell structures and processes and eukaryotic cell structures and processes? What technologies were developed based on our understanding of cell division and cellular structures? How are cell components used in biotechnology to make functional products? What is meiosis? How does sexual reproduction provide genetic diversity? What is nanotechnology?	Compare prokaryotic and eukaryotic cellular structures and cellular processes. View animations comparing plant and animal eukaryotic cells on the Internet. (e.g., http://www.cellsalive.com/cells/cell_model.htm (accessed April 9, 2010), etc.). View animations comparing plant and animal eukaryotic cells on the Internet. (e.g., http://www.cellsalive.com/meiosis.htm (accessed April 9, 2010), etc.). Research different technologies that have been developed due to our increasing understandings about cell division and cellular structures. Make a chart comparing meiosis and mitosis. Create a chart listing existing biotechnology products, their purpose and which part of the cell they are based on, include how the product is used and received in the marketplace.

Big Idea:	**Biomolecules are the basis of many biotechnology products and applications, requiring an understanding of cellular processes at a molecular level.**

Advanced Understandings	Key Questions	Learning Suggestions
Cell membranes regulate movement of molecules into and out of cells. Regulating this movement is important for managing cell processes and maintaining homeostasis (i.e., passive transport, active transport and endo/exocytosis). Only specific types of molecules are transported between cells and capillaries (i.e., carbon dioxide, oxygen, hormones, nutrients, nitrogenous wastes). DNA consists of two long polymers of nucleotides, with backbones made of sugars and phosphate groups joined by ester bonds. Significant scientific discoveries have built our understanding of the structure and function of the DNA molecule (e.g., Watson and Crick, Matthew Meselson and Franklin Stahl, etc.). Knowledge of enzymes can be applied to technologies involving biofuels and genetic engineering.	What is the function of cell membranes? Why is the regulation of molecules across cell membranes important to cells? What types of molecules are transported between cells and capillaries and what are their purposes? What molecule makes up the genetic material and how does it look? How do carbon-based molecules interact with each other? How are enzymes used to create new products in biotechnology industries and pharmaceutical research?	Explain how cell membranes regulate movement of molecules into and out of cells. Describe why the regulation of molecules across cell membranes is important for managing cell processes and maintaining homeostasis (i.e., passive transport, active transport and endo/exocytosis). Explain why only specific types of molecules are transported between cells and capillaries (i.e., carbon dioxide, oxygen, hormones, nutrients, nitrogenous wastes). Explain how carbon-based molecules interact with each other. Conduct an inquiry to observe the effect of enzymes on common substances. Explain a technology which uses enzymes to create new products (e.g., DNA nanotechnology, biofuels, production of antibiotics, etc.).

Genetics

Big Idea: **Cells, tissues and organisms derive their physical characteristics and function through the expression of genes to functional molecular products. The molecules and processes involved in gene expression have important applications in biotechnology.**

Advanced Understandings	Key Questions	Learning Suggestions
DNA is transcribed into sequences of bases in RNA molecules and is finally translated into sequences of amino acids in proteins. Restriction enzymes cut DNA molecules into smaller fragments and ligases reassemble them. The process of protein synthesis utilizes mRNA, tRNA, amino acids and ribosomes. rDNA molecules can be transferred into cells to create modified organisms. Regulatory proteins play a role in the control of gene expression in both eukaryotes and prokaryotes. Many factors affect the regulation of gene expression. Techniques and technologies used to diagnose early genetic problems in humans include amniocentesis, chorionic villus sampling, maternal serum screens, etc.	What is the Central Dogma of Molecular Biology and its significance? What is rDNA and what happens when it is transferred into cells? What is the significance of the function of regulatory proteins? What is gene expression? What factors affect the regulation of gene expression? What are the risks and benefits of techniques that are used to diagnose early genetic problems in humans?	Describe the process of DNA transcription. Describe the process of DNA translation. Watch an animation of DNA transcription and translation on the Internet. Explain how restriction enzymes and ligases cut and reattach DNA strands. Create a flow chart diagramming the process of protein synthesis. Research an organism in which rDNA has been transferred to create a modified organism. Describe an example of how regulatory proteins control gene expression in a specific organism. Describe a specific case of gene expression (e.g., heat shock proteins, Lac operon, etc.). Describe a techniques or technologies used to diagnose early genetic problems in humans and explain its risks and potential benefits.

Big Idea:	**The concepts and mechanisms of genetic propagation and heredity play an important role in numerous biotechnology products, processes and applications.**

Advanced Understandings	Key Questions	Learning Suggestions
DNA, genes, chromosomes, alleles, mitosis and meiosis all have a role in the transmission of hereditary characteristics from generation to generation. Genetic disorders can be caused by chromosomal abnormalities or other genetic mutations. Ethical issues may arise as a result of genetic testing for these diseases. Genetic engineering requires knowledge of DNA as well as familiarity with genetic engineering tools and techniques (e.g., restriction enzymes, recombinant DNA, DNA amplification, bacterial vectors, viral vectors, Polymerase Chain Reaction, gel electrophoresis, DNA sequencing, etc.).	What roles do DNA, genes, chromosomes, alleles, mitosis and meiosis have in the transmission of hereditary characteristics from generation to generation? What is a gene mutation? What can cause abnormalities in chromosomes? What forms of testing or screening exist to identify genetic disorders? What is genetic engineering? What tools and techniques are used for genetic engineering?	Investigate an issue related to the application of gene technology in humans and evaluate the design of technological solutions and the way they function, using genetic principles (e.g., genetic counselling, various methods of detecting genetic disorders, etc.). Describe examples of common gene mutations. Research a disease or irregularity caused by a chromosomal alteration. Research various types of genetic testing or screening. Discuss the ethical implications of testing and its resulting information for families. Participate in an activity that involves gel electrophoresis. Describe the purpose of DNA amplification. Describe an example in which DNA is transferred using a viral vector.

Big Idea:	**The Human Genome Project has been a catalyst for the integrated and holistic study of sets of molecules (e.g., DNA, proteins, metabolites, etc.), collectively called "omics." These related areas of research have the potential to revolutionize the diagnosis and treatment of disease.**

Advanced Understandings	Key Questions	Learning Suggestions
"Omics" research areas inform our understanding of complex biological processes and provide comprehensive analysis of living organisms and their interactions with their environments. Genomic and proteomic technologies provide potential risks (e.g., privacy, financial, ethical, etc.) and benefits (e.g., knowledge of predisposition to disease, analysis, prevention and treatment of disease, etc.) to society. The Human Genome project and other genome sequencing projects have created potential medical and ethical implications for society. Genomics is the study of all of the genes in an organism and the interactions among them and their environment, whereas proteomics examines all of the proteins in a given cell or organism. Both fields are important to the diagnosing and treatment of diseases. Current studies in molecular biology, genomics and proteomics support the evidence for biological variation. Computational biology and bioinformatics are essential in biotechnology and help make sense of the massive amounts of data gathered (e.g., in genomic studies including annotating genomes, predicting and analyzing genetic patterns and protein sequences and creating algorithms for diagnostics, etc.).	What is meant by “omics?” Why are “omics” research areas important? What are the potential benefits and risks of genomic and proteomic technologies? Why does the Human Genome Project have potential medical and ethical issues? How are genomics and proteomics similar and different? Why are both genomics and proteomics important fields? What role does computer science have in furthering biotechnology and biosciences research?	List examples of “omics” research areas. Analyze, from a variety of perspectives, the risks and benefits to society of genomic and proteomic technologies (e.g., risks: privacy, financial, ethical, etc.; benefits: knowledge of predisposition to disease, analysis, prevention and treatment of disease, etc.). Explore the potential medical and ethical implications on the Human Genome project and other genome sequencing projects on society. Compare and contrast genomics and proteomics. Discuss the importance of genomics and proteomics. Investigate an area of computer science that is integrated with biotechnology and biosciences research (e.g., informatics, nanobiotechnology, DNA nanobiotechnology, etc.). Explain the purpose of computational biology and bioinformatics and find examples of current research using either one of these, including the significance of the research and any ethical considerations that may arise.

Biodiversity

Big Idea: Biological variation exists at all levels, from micro to macro (e.g., molecules to populations).

Advanced Understandings	Key Questions	Learning Suggestions
Modern techniques used for classification of organisms include DNA/RNA comparisons, molecular clocks, radioactive dating, structural information, embryology, cellular structure, behaviour, etc. These methods are significantly different from those utilized by early scientists such as Aristotle or Linnaeus. Species diversity and genetic diversity are important for maintaining viable ecosystems. Biological variation can occur through both artificial and natural evolutionary mechanisms (e.g., natural selection, artificial selection, genetic mutations, rDNA, etc.). The use of microorganisms in biotechnology can have ethical impacts on the environment and society.	What modern techniques are used to classify organisms? How do modern classification methods differ from those used historically? Why is species diversity and genetic diversity important for maintaining viable ecosystems? How does biological variation occur?	Research modern techniques used for classification of organisms (e.g., DNA/RNA comparisons, molecular clocks, radioactive dating, structural information, embryology, cellular structure or behaviour, etc.) and compare these techniques with the methods utilized by early scientists such as Aristotle or Linnaeus. Research examples of instances when species diversity has affected the health of an ecosystem. Describe how biological variation can occur, including both artificial and natural evolutionary mechanisms (e.g., natural selection, artificial selection, genetic mutations, rDNA, etc.). Examine the ethical issues surrounding use of microorganisms in biotechnology from a variety of perspectives.

Big Idea:	**Humans have a long history of affecting biodiversity. This continues today with the application of advanced biological knowledge and modern technologies.**	
Advanced Understandings	**Key Questions**	**Learning Suggestions**
Genetically modified plants and animals can have biological, social, ethical and environmental risks and benefits. Reproductive technologies (e.g., cloning, recombinant DNA, etc.) can impact the genetic diversity of a species (e.g., farm animals, crops, etc.). Genetic manipulations at the DNA level are challenging long-held views of what is considered to be plant and animal. Transgenic organisms are organisms which have been modified with genetic material from other species.	What are some of the social, ethical and environmental risks and benefits of genetically modified plants and animals? How can reproductive technologies impact the genetic diversity of a species? Where does the plant-animal "boundary" blur? What are transgenic organisms? What is the role of transgenic organisms?	Identify the risks and benefits of genetically modified animals and plants that can reach the market and cost less to feed vs. unknown consequences for the ecosystem. Compare and contrast various forms of reproductive technologies in term of their impact on the diversity of species. Describe how genetic manipulations at the DNA level have challenged long held views of what is considered plant and animal. Define transgenic organisms and provide some examples of applications (e.g., stem cells, research to investigate a wide range of diseases and conditions, etc.)

Part Six: Canadian Contributions to Biotechnology

Canada has contributed to the scientific knowledge and applications that have led to biotechnology innovations. Below are some examples of well-known people and their contributions. This list is just a snapshot of the people who have contributed to biosciences research and biotechnology innovations.

Area	Name	Contribution
agriculture plant ecology	Abrams, Sue	Abrams is an organic chemist currently at the National Research Council Plant Biotechnology Institute in Saskatoon, Saskatchewan who is studying the control switches for a powerful plant hormone that regulates growth, development and resistance to stress. Source: http://www.nrc-cnrc.gc.ca/eng/education/innovations/scientists/abrams.html (accessed April 9, 2010).
molecular biology	Altman, Sid	Altman discovered catalytic RNA, for which he won the Nobel Prize in 1989. Source: http://www.science.ca/scientists/scientistprofile.php?pID=3 (accessed April 9, 2010).
agriculture microbiology	Babiuk, Lorne	Babiuk is an international authority in veterinary virology and immunology. Source: http://www.science.ca/scientists/scientistprofile.php?pID=401 (accessed April 9, 2010).
genetics	Baird, Patricia A.	Baird's internationally renowned work has focused on the population distribution of genetic disorders such as Down Syndrome and on the social, ethical and health results of new knowledge of human reproductive biology and genetics. Source: http://www.science.ca/scientists/scientistprofile.php?pID=258 (accessed April 9, 2010).
medicine pharmaceuticals	Banting, Sir Frederick Grant and Best, Charles Herbert	Banting and Best were the co-discovers of insulin; Banting received the Nobel Prize in 1923. Outraged that his co-worker had not also been awarded the prize, he gave half his share to Best. Sources: http://www.science.ca/scientists/scientistprofile.php?pID=114 (accessed April 9, 2010). http://www.sciencetech.technomuses.ca/english/about/hallfame/u_i10_e.cfm (accessed April 9, 2010). http://www.science.ca/scientists/scientistprofile.php?pID=123 (accessed April 9, 2010). http://www.cdnmedhall.org/dr-charles-herbert-best (accessed April 9, 2010).
genetics	Barr, Murray Llewellyn	In 1949, Barr discovered sex chromatin, a substance made of DNA and protein, a discovery which made it possible to determine the cellular sex of an individual. Barr and his colleagues also devised the buccal smear test, whereby cells from the patient's mouth are taken and examined for chromosomal defects. This test is now used extensively to screen patients, including newborn babies. Sources: http://www.science.ca/scientists/scientistprofile.php?pID=119 (accessed April 9, 2010). http://www.cdnmedhall.org/dr-murray-barr (accessed April 9, 2010).
aquaculture metabolism	Battle, Helen Irene	Battle pioneered the idea of using fish eggs to study the effects of cancer causing substances on cell growth. Source: http://www.science.ca/scientists/scientistprofile.php?pID=400 (accessed April 9, 2010).
organic chemistry medicine	Beer, Charles Thomas and Noble, Robert Laing	Dr. Beer's major contribution to medicine was the isolation of the anti-cancer drug "vinblastine" at the University of Western Ontario in 1958. He worked closely with the late Dr. Robert L. Noble to develop vinblastine from the leaves of the Madagascar periwinkle plant, *Vinca rosea*. Vinblastine is one of the most useful chemotherapeutic agents available and its discovery and isolation is considered to be a milestone in the history of cancer chemotherapy, particularly for the management of Hodgkin's disease and testicular cancer. Source: http://www.cdnmedhall.org/dr-charles-thomas-beer (accessed April 9, 2010). http://www.cdnmedhall.org/dr-robert-laing-noble (accessed April 9, 2010).
aquaculture	Bernatchez, Louis	Bernatchez is a Canadian molecular biologist studying the genetics of fish populations. He uses DNA analysis to study

Area	Name	Contribution
molecular biology		genetic change and evolution in fish. Source: http://www.science.ca/scientists/scientistprofile.php?pID=358 (accessed April 9, 2010).
genetics	Boulianne, Gabrielle	By inserting fruit flies with a human gene known to protect against oxidative damage, Boulianne and her team were able to increase the normal lifespan of the fruit fly by 40%. This has great significance in scientific understanding not only of the natural aging process, but of degenerative diseases such as Amyotrophic Lateral Sclerosis (Lou Gehrig's disease) and Alzheimer's. Sources: Dr. Boulianne's website, Women at the Frontiers of Exxcellence, U of T Bulletin June 22, 1998 (accessed April 9, 2010). http://www.science.ca/scientists/scientistprofile.php?pID=269 (accessed April 9, 2010).
botany	Callen, Eric Ottleban	Callen is the founder and developer of human coprolite (dried or fossilized piece of animal excrement) analysis. Dried human coprolites, typically less than 10,000 years old, can be returned to their original texture, odour and "freshness" by a technique developed by Dr. Callen in 1955. Today, human DNA can be extracted from coprolites and can give a picture of what people were like and what life was like up to 90,000 years ago. Scientists can even tell when our ancestors began to speak by looking for the FOXP2 gene in the DNA. When the presence of the FOXP2 gene is detected, it means that the person was capable of the jaw movements required for speech. Source: http://www.science.ca/scientists/scientistprofile.php?pID=421 (accessed April 9, 2010).
medicine pharmaceuticals	Chown, Bruce	Chown studied Rh disease (erythroblastosis fetalis) and developed the serum which now prevents this illness worldwide. Source: http://www.science.ca/scientists/scientistprofile.php?pID=337 (accessed April 9, 2010).
biochemistry	Chrétien, Michel and Seidah, Nabil G.	Chrétien and Seidah were co-discoverers of convertases, enzymes that cleave proteins to create biologically active chemicals such as hormones. Sources: http://www.science.ca/scientists/scientistprofile.php?pID=340 (accessed April 9, 2010). The Canadian Protein Engineering Network (PENCE) (accessed April 9, 2010). http://www.science.ca/scientists/scientistprofile.php?pID=341 (accessed April 9, 2010).
aquaculture mathematical bioeconomics	Clark, Colin Whitcomb	Clark invented mathematical bioeconomics. He applied his mathematical knowledge to accurately identify and analyze renewable resources like fisheries and how to manage them so that that some of the resource is used, but enough is left to reproduce for future harvests. Source: http://www.science.ca/scientists/scientistprofile.php?pID=139 (accessed April 9, 2010).
technology	Corkum, Paul	Corkum developed the attosecond laser imaging of molecules and atoms. Source: http://www.science.ca/scientists/scientistprofile.php?pID=448 (accessed April 9, 2010).
business microbiology	Costerton, J. William (Bill)	Costerton pioneered biofilm microbiology. Costerton and his team have applied their knowledge to developing new technologies in areas ranging from oil production to bacteria-resistant medical devices. He holds several biological patents and is president of the Microbios company. Source: http://www.science.ca/scientists/scientistprofile.php?pID=143 (accessed April 9, 2010).
pharmaceuticals biochemistry	Cullis, Pieter	Cullis conducts basic and applied research on liposomes as models of biological membranes and as drug delivery vehicles, with particular emphasis on delivery of genetic drugs such as antisense oligonucleotides and plasmids containing therapeutic genes. The major application is for treatment of cancer. Source: http://www.science.ca/scientists/scientistprofile.php?pID=375 (accessed April 9, 2010).
genetics	Derick, Carrie M.	Derick pioneered work in heredity. She became the first woman ever appointed to a full professorship at a Canadian university. Her research on heredity was read by scientists around the world and paved the way for the future study of genetics. She was one of the few women listed in American Men of Science (1910). Source: http://www.science.ca/scientists/scientistprofile.php?pID=146 (accessed April 9, 2010).

Area	Name	Contribution
agriculture genetics	Downey, Richard Keith	Downey is the father of canola, which is an edible, high value, high protein crop used worldwide in the form of cooking oil and livestock feed. Canola is named for "Canada" and "oil". Source: http://www.science.ca/scientists/scientistprofile.php?pID=348 (accessed April 9, 2010).
biochemistry	Farrell, Leone N.	Farrell pioneered a key laboratory technique that led to the creation of the Salk polio vaccine. She did not discover the vaccine, but she figured out a way to stimulate the growth of microorganisms in the lab, and this technique was eventually used to mass-produce the Salk polio vaccine. Source: http://www.science.ca/scientists/scientistprofile.p hp?pID=438 (accessed April 9, 2010).
microbiology immunology	Finlay, B. Brett	Finlay is one of the world's foremost experts on the molecular understanding of the ways bacteria infect their hosts. He is best known for his work with *Salmonella* and *Escherichia coli*. He has specialized in the strategies which these bacteria use in the early stages of infection, and how they avoid the host cells' self-defence mechanisms. His research has led to the development of a vaccine for cattle. Source: http://www.science.ca/scientists/scientistprofile.php?pID=359 (accessed April 9, 2010).
molecular biology	Gauldie, Jack	Gauldie was the first to isolate and identify interleukin-6, the molecule responsible for the body's immediate immune response to injury. He has worked to use genes to stimulate the immune system to fight diseases such as cancer, arthritis, asthma and tuberculosis. He calls this approach "gene therapeutics" - the use of a gene as a drug. Gauldie's team is the first in Canada using these techniques. Source: http://www.science.ca/scientists/scientistprofile.php?pID=361 (accessed April 9, 2010).
medicine	St George-Hyslop, Peter Henry	In 2000, St George-Hyslop and his team of researchers identified a key protein that causes nerve cell degeneration. This new development followed their early discoveries in 1995 of the genes responsible for the early onset of Alzheimer disease. Although more studies and tests are required, these findings could lead to a new drug that would regulate the progression of Alzheimer disease. Source: http://www.science.ca/scientists/scientistprofile.php?pID=392 (accessed April 9, 2010).
genetics	Gros, Philippe	Gros cloned the Nramp gene and the mdr gene. Source: http://www.science.ca/scientists/scientistprofile.php?pID=166 (accessed April 9, 2010).
bioenergy environment	Guiot, Serge	Guiot leads the environmental bioengineering research group at the National Research Council Biotechnology Research Institute in Montreal. This group is focused on harnessing bacteria to produce energy sources such as methane and hydrogen. Source: http://www.nrc-cnrc.gc.ca/eng/education/innovations/scientists/guiot.html (accessed April 9, 2010).
environment ecology	Hebert, Paul	Hebert developed a species ID system called 'DNA barcoding', which uses a small DNA fragment to discriminate species. Source: http://www.science.ca/scientists/scientistprofile.php?pID=440 (accessed April 9, 2010)
technology	Hillier, James and Prebus, Albert	Hillier and Prebus invented the world's first practical electron microscope. Source: http://www.sciencetech.technomuses.ca/english/about/hallfame/u_i29_e.cfm (accessed April 9, 2010).
pharmaceuticals	Jennings, Harold	Jennings' research resulted in a highly effective synthetic vaccine that protects people of all ages against Meningitis-C, including babies as young as 2 months. By linking the Group C meningococcal polysaccharide to a related protein vaccine used against infant tetanus, Dr. Jennings was able to produce a more responsive vaccine that stimulates the production of antibodies against meningitis in infants. Source: http://www.nrc-cnrc.gc.ca/eng/education/innovations/scientists/jennings.html (accessed April 9, 2010).
medicine	Kalow, Werner	Kalow brought pharmacology and genetics together into a subspecialty called pharmacogenetics and discovered genetic variants of plasma cholinesterase.

Area	Name	Contribution
		Source: http://www.science.ca/scientists/scientistprofile.php?pID=410 (accessed April 9, 2010).
environment	Kennedy, Sean. W.	Kennedy is a member, and the only Canadian, on the Scientific Advisory Board for Toxicogenomics to explore and evaluate how toxicogenomics can be used for regulatory purposes.
aquaculture biochemistry	Lall, Santosh	Lall designs diets that help the aquaculture industry meet consumer demands for fresh fish. To understand fish nutrition, we need to understand their biology and biochemistry. In our lab, we tackle nutritional problems from the organism, cellular and molecular (DNA and RNA) level. Source: http://www.nrc-cnrc.gc.ca/eng/education/innovations/scientists/lall.html (accessed April 9, 2010).
pharmaceuticals microbiology immunebiology	Mak, Tak Wah	Mak discovered the T-Cell receptor, a key to the human immune system, and led a team that produced 20 patented molecular discoveries for use in drug development. Sources: http://www.science.ca/scientists/scientistprofile.php?pID=15 (accessed April 9, 2010). http://www.cdnmedhall.org/dr-tak-wah-mak (accessed April 9, 2010).
cell biology	Masui, Yoshio	Masui discovered the cell growth switch; he also invented many original techniques to assist his studies of cell division, a quantitative method for microinjection in 1971, microextraction in 1976 and cell-free “in-vitro” mitosis in 1983. Source: http://www.science.ca/scientists/scientistprofile.php?pID=198 (accessed April 9, 2010).
biochemistry	Menten, Maude	Menten developed the Michaelis-Menten equation for enzyme kinetics. This equation gives an expression for the rate of an enzyme reaction and became fundamental to the interpretation of how an enzyme reacts on its substrate. Source: http://www.science.ca/scientists/scientistprofile.php?pID=200 (accessed April 9, 2010).
molecular biology	Miller, Freda	Miller discovered that stem cells could be harvested from human adult skin and that they could be used to grow nerve cells that could potentially help people with spinal cord injuries or Parkinson's disease. Source: http://www.science.ca/scientists/scientistprofile.php?pID=446 (accessed April 9, 2010).
stem cells	Nagy, Andras	Nagy discovered a new method of creating stem cells that could lead to possible cures for devastating diseases including spinal cord injury, macular degeneration, diabetes and Parkinson's disease. Source: http://esciencenews.com/articles/2009/03/01/mount.sinai.hospital (accessed April 9, 2010).
technologies organic chemistry	Ogilvie, Kelvin Kenneth	Ogilvie developed the “Gene Machine” (1980), an automated process for the manufacture of DNA, which made it possible to build DNA sequences in a matter of hours rather than in months. He is the author of 12 patents, including one for Ganciclovir, a drug used worldwide to fight infections that occur when one’s immune system is weakened. Ogilvie also developed a general method for the chemical synthesis of large RNA molecules, demonstrated by the first total chemical synthesis or a functional Transfer RNA (tRNA) molecule, which is still the basis for RNA synthesis worldwide. Source: http://www.science.ca/scientists/scientistprofile.php?pID=203 (accessed April 9, 2010).
cell biology molecular biology	Pawson, Anthony	Pawson is an international leader in the field of cell signalling research. His ground-breaking studies have focused on the signals that are transmitted between cells in the human body and how this forms a pattern of communication. By understanding cellular communication, scientists can track how the pattern of communication can “break down” in conditions such as heart disease and immune system deficiencies. Sources: http://www.cdnmedhall.org/dr-anthony-pawson (accessed April 9, 2010). http://www.science.ca/scientists/scientistprofile.php?pID=394 (accessed April 9, 2010).
forestry	Pomerleau, René	Pomerleau is a pioneer in plant pathology and one of the first scientific interpretive writers in Quebec.
cell biology stem cells	Rossant, Janet	Rossant is internationally recognized for her pioneering research in mouse genetics; she is also a major influence in developmental biology, stem cells and cell lineage. Her major findings are related to the question of how genetically identical cells adopt distinct characteristics during embryo development.

Area	Name	Contribution
		Source: http://www.science.ca/scientists/scientistprofile.php?pID=393 (accessed April 9, 2010).
agriculture botany	Saunders, Sir Charles	Saunders developed Marquis wheat, a strain that made Canada famous for its hard red spring wheat which matures early, produces high volume and is excellent for bread. Source: http://www.science.ca/scientists/scientistprofile.php?pID=216 (accessed April 9, 2010).
genetics	Siminovitch, Louis (Lou)	Siminovich is a pioneer in human genetics; researcher into the genetic basis of muscular dystrophy and cystic fibrosis. Sources: **http://www.cdnmedhall**.org/dr-louis-siminovitch (accessed April 9, 2010). http://www.science.ca/scientists/scientistprofile.php?pID=399 (accessed April 9, 2010). http://www.sciencetech.technomuses.ca/english/about/hallfame/u_i41_e.cfm (accessed April 9, 2010).
DNA nanotechnology biochemistry material science	Sleiman, Hanadi	Sleiman led a team of researchers in a major breakthrough in the development of nanotubes that could one day deliver drugs to specific diseased cells. Sources: http://www.news-medical.net/news/20100318/McGill-researchers-pioneer-major-breakthrough-in-DNA-nanotechnology.aspx (accessed April 9, 2010).
forestry insect pathology	Smirnoff, Wladimir A.	Smirnoff's research led to the development of a biological insecticide and significant contributions to insect pathology. Source: http://www.nrcan.gc.ca/com/deptmini/traipion/wladimirsmirnoff-eng.php (accessed April 9, 2010)
organic chemistry	Smith, Michael	Smith won the Nobel Prize in chemistry in 1993 for discovering site-directed mutagenesis - that is, how to make a genetic mutation precisely at any spot in a DNA molecule. Sources: http://www.science.ca/scientists/scientistprofile.php?pID=18&pg=1 (accessed April 9, 2010). http://www.sciencetech.technomuses.ca/english/about/hallfame/u_i21_e.cfm (accessed April 9, 2010). http://www.cdnmedhall.org/dr-michael-smith (accessed April 9, 2010).
cell biology	Till, James Edgar and McCulloch, Ernest	Till and McCulloch established the concept of stem cells and set the framework in which stem cells are studied today. Sources: http://www.cdnmedhall.org/dr-james-edgar-till (accessed April 9, 2010). http://www.cdnmedhall.org/dr-ernest-mcculloch (accessed April 9, 2010).
genetics	Tsui, Lap-Chee	Tsui found the gene that causes cystic fibrosis. Source: http://www.science.ca/scientists/scientistprofile.php?pID=19&pg=1 (accessed April 9, 2010).
genetics	Uchida, Irene Ayako	Uchida's work in genetics focused on the study of twins, children with congenital heart diseases and those with a variety of other anomalies such as Down syndrome. Uchida believes geneticists may be able to find out how to deactivate one of the chromosomes in an individual with trisomy. This happens naturally during the embryonic development of all women - one of their X chromosomes is always deactivated. If geneticists can find a technique to deactivate certain chromosomes such as the extra ones at numbers 21, 13 or 18, the related genetic conditions may be cured at an early embryonic stage. Sources: http://www.science.ca/scientists/scientistprofile.php?pID=21&pg=1 (accessed April 9, 2010). http://www.collectionscanada.gc.ca/femmes/002026-415-e.html (accessed April 9, 2010).
biochemistry	Wiesner, Karel	Wiesner developed Canada's leading school of natural products chemistry - the extraction and characterization of naturally occurring chemicals from plants and animals. He determined the chemical structure and synthesis of very complicated alkaloids and made major contributions to the fields of terpenoids and steroids. Source: http://www.science.ca/scientists/scientistprofile.php?pID=231 (accessed April 9, 2010).

Glossary

allele	a form of a particular gene at a specific position on a chromosome (e.g., blue and brown eyes in humans are determined by different alleles of the eye colour gene)
amino acid	a building block for proteins and composed of organic molecules; amino acids all contain a basic amino group (NH_2) and an acidic carboxyl group (COOH)
amniocentesis	a prenatal procedure that examines the chromosomes of fetal cells; it is commonly used to diagnose chromosome conditions (like Down syndrome) and genetic conditions (like cystic fibrosis) during pregnancy
anabolic steroid	a drug which mimics the effects of the male steroids testosterone and dihydrotestosterone; these drugs increase protein synthesis within cells, which results in the buildup of cellular tissue (anabolism), especially in muscles
antibiotic	a substance or compound that kills or inhibits the growth of microorganisms
antibody	a large defense protein that is produced in response to an antigen (often a virus or bacterium) which combines with and neutralizes the antigen
aquaculture	a type of farming involving freshwater and saltwater organisms, including fish, molluscs, crustaceans and aquatic plants, under controlled conditions
artificial insemination	a process by which a sperm sample is placed into the female reproductive tract for the purpose of improving the female's chance of getting pregnant using means other than sexual intercourse
artificial selection	an intentional breeding by humans towards a desired trait in a plant, animal or other organisms which is of value (usually economic) to humans (also called selective breeding)
asexual reproduction	a form of reproduction in which an organism produces one or more clones of itself using different mechanisms such as fission or budding
biodiversity	a number, variety and variability of living organisms within a given place at a given time
bioenergy	a subset of biotechnology focused on harnessing and producing renewable forms of energy from organic material
bioethics	a subfield of ethics that explores ethical questions related to the life sciences
biofuel	a gaseous, liquid or solid fuel that is in some way derived from biological material (plants, sewage, dry waste, etc.) through combustion or fermentation

bioinformatics	an area of research using computers to solve information problems in the life sciences; it mainly involves the creation of extensive electronic databases on genomes, protein sequences, etc., and also involves techniques such as the three-dimensional modeling of biomolecules and biologic systems
biomolecule	an organic molecule that is an essential part of a living organism
biopesticide	a pesticide consisting of naturally occurring or genetically engineered microorganisms
bioremediation	a use of organisms (e.g., plants, microorganisms, fungi, etc.) to clean up pollution from a contaminated site or other environmental situations
biosensor (chemical)	a chemically-based device that is able to detect and/or measure the presence of certain molecules (e.g., DNA, antigens, glucose, active ingredients of pesticides, etc.)
biosensor (electronic)	an electronic device that is able to detect and measure the presence of biomolecules such as sugars or DNA segments
biotechnology	a business sector and scientific discipline which deals with the use of living organisms or their products in industrial processes; not an industry *per se*, but rather a group of related technologies that is used by many industries
bovine growth hormone	a protein hormone, produced in a cow's pituitary gland, that increases the efficiency of the cow in converting its feed into milk; increases milk production in cows, promotes cell growth in healing tissues of all ages of cattle and promotes body growth of young cattle
business plan	a set of documents prepared by company management to summarize the company's operational and financial objectives for the near future (one to three years); it guides the company's policies and strategies and is continually modified as conditions change and new opportunities and/or challenges emerge
carbohydrate	a compound or molecule that is composed of carbon, oxygen and hydrogen in the ratio of 2H:1C:1O; it can be a simple sugar such as sucrose or fructose, or a complex polysaccaride polymer such as chitin
chorionic villus sampling (CVS)	a procedure for first-trimester prenatal diagnosis that examines the chromosomes of fetal cells; the aim is to diagnose severe abnormalities afflicting the fetus such as Down syndrome or cystic fibrosis
chromosome	a tightly coiled strand of genes (DNA) located in the cell nucleus that determines the inheritance of traits; each chromosome has a fixed number of genes, and every species has a characteristic number of chromosome pairs (e.g., humans have 23 pairs, mice have 19 pairs, pea plants have 7 pairs, etc.)
cladistics	a system of taxonomic classification of organisms that is based upon (determined) similar lines of selected shared traits
cloning	a process of asexually producing a group of cells (clones), all genetically identical, from a single ancestor
computational biology	see *bioinformatics*

consequence map	a cognitive or mental map that outlines the consequences of an action or event
copyright	a legal right registering ownership for any original literary, dramatic, musical or artistic work by the creator of the work; it can be registered from the moment this work is created
cord bank	a bank or storage facility for umbilical cord embryonic stem cells
DNA (deoxyribonucleic acid)	an abbreviation for deoxyribonucleic acid, the essential molecule of heredity; the twisted ladder of the base pairs of the DNA molecule contains the chemically coded instructions to construct and maintain a living organism; the specific sequence of DNA's bases stores all of the organism's hereditary information
DNA amplification	a technique to amplify a single or few copies of a piece of DNA across several orders of magnitude, generating thousands to millions of copies of a particular DNA sequence
DNA computing	a form of computing which uses DNA molecules instead of digital logic circuits
DNA fingerprint	a technique used to assist in the identification of individuals on the basis of their respective DNA profiles
DNA profiling	an encrypted set of numbers that reflect a person's DNA makeup, which can also be used as the person's identifier (also called DNA testing, DNA typing, or genetic fingerprinting); DNA profiling should not be confused with full genome sequencing
DNA sequencing	a lab technique used to find out the sequence of nucleotide bases (adenine, guanine, cytosine and thymine) in a DNA molecule or fragment
diagnostic	a method and/or process of diagnosing disease or illness
embryology	a subfield of developmental biology studying the development of an embryo from a single-celled zygote to a multicellular structure of distinct form and shape
embryo transfer	a step in the process of *in vitro* fertilization (IVF) involving the placement of a laboratory-fertilized egg into the fetus
endocytosis	a process by which cells absorb molecules (such as proteins) from outside the cell by engulfing it with their cell membrane
enzyme	a protein that acts as a catalyst, increasing the rates at which biochemical reactions proceed
enzyme induction	a process in which a molecule induces (i.e., initiates or enhances) the expression of an enzyme
ethics	a branch of philosophy that seeks to address questions about morality
eukaryote	a cell or organism with a membrane-bound, structurally discrete nucleus and other well-developed subcellular compartments; eukaryotes include all organisms except viruses, bacteria and cyanobacteria (blue-green algae)
exocytosis	a process by which cellular material is discharged from a cell

feasibility study	an analysis and evaluation of a proposed project to determine if it is technically feasible, feasible within the estimated cost and will be profitable; mainly conducted when large amounts of money are at stake
financial plan	a long-term profit plan focusing on greater return on assets, growth in market share and solving foreseeable problems
gel electrophoresis	a technique using an electric current applied to a gel matrix; used for the separation of deoxyribonucleic acid (DNA), ribonucleic acid (RNA) or protein molecules
gene	a fundamental physical and functional unit of heredity
gene expression	a translation of information encoded in a gene into protein or RNA; it is used in the synthesis of a functional gene product
gene therapy	a process of inserting genes directly into selected cells to correct a genetic defect or disease
gene bank	a collection of cloned DNA fragments that contains all the genetic information of a particular organism
genetic counselling	a professional interaction between health care providers with specialized knowledge of genetics (a genetic counsellor) and an individual or family which provides information and advice about genetic testing
genetic disorder	an illness caused by abnormalities in genes or chromosomes
genetic engineering	a technique of removing, modifying or adding genes to a living organism; also known as recombinant DNA (rDNA) technology
genetically modified organism (GMO)	an organism (plant, animal or microorganism) that has had its genetic material altered in order to give the organism new characteristics that are not naturally found in the organism; for example, the DNA from food crops may be genetically modified to increase the crop's resistance to insects or disease, or to improve taste
genetic mutation	a permanent change or structural alteration in the DNA or RNA
genetic regulation	a process of turning genes on and off
genome	an organisms entire genetic information content
genome sequencing	a process of determining all the base pairs for an organism
genomics	a study of the complete DNA sequences, or genomes, in living things, and can include the interaction of genomes with various environmental influences; it differs from classical biological research in its large scale, broad scope and intense reliance on data collection, analysis and information technology (bioinformatics)
genotype	a specific set of alleles contained in the DNA of a specific organism
GMO	see *genetically modified organism*

Green Revolution	a time of dramatic increase in crop productivity during the latter part of the 20th century due to advances in genetics, petrochemicals and machinery
heredity	a passing of traits from one generation to another
homeostasis	a property of a system, either open or closed, that regulates its internal environment and tends to maintain a stable, constant condition
Human Genome Project	an international effort to map and sequence all human genes; the motivation behind the project was that sequencing and identifying all human genes would help us to better understand genetic disorders and find ways to diagnose, treat and perhaps prevent these conditions
human immunodeficiency virus (HIV)	a virus that causes *acquired immunodeficiency syndrome* (AIDS), a condition in humans in which the immune system begins to fail, leading to life-threatening opportunistic infections
hybridization	a process of joining two complementary strands of DNA or one each of DNA and RNA to form a double stranded molecule
industrial design	a type of IP referring to the visual features of shape, configuration, pattern or ornament (or any combination of these features) applied to a finished article made by hand, tool or machine; the design must be original and can be two- or three-dimensional
intellectual property (IP)	a legal right to exclude others from using "property" created by an owner; refers to creations of the mind, such as inventions, literary and artistic works, symbols, names, pictures, designs and models used in business
investment fund	an investment of money committed, or property acquired, for future income
in vitro fertilization (IVF)	a reproductive technology where sperm fertilize the egg in a laboratory dish and the fertilized egg is put back into the uterus for the pregnancy to be established
Krever Inquiry	a Royal Commission established by the Canadian Government in October 1993, headed by Mr Justice Horace Krever; it was set up to investigate allegations that the system of government, private and non-governmental organizations responsible for supplying blood and blood products to the health care system had allowed contaminated blood to be used
Lac operon	an operon in *Escherichia coli (E. coli)* that codes for three enzymes involved in the metabolism of lactose
ligase	an enzyme used to catalyze the joining together of two separate molecules in an energy-requiring process
Linnaean system	a formal system for classifying every organism, living or extinct; is named after Carl Linnaeus (1707-1778), a Swedish naturalist who was the first to create a uniform system of naming organisms
lipid	a fatty, waxy or oily compound that is characteristically insoluable in water but readily soluble in organic solvents; its main biological functions include energy storage, a structural component of cell membranes, and as an important signalling molecule
macromolecule	a very large molecule (e.g., proteins, carbohydrates, etc.)

meiosis	a type of cell division that occurs only in reproductive organs resulting in the production of gametes (cells) with half the number of chromosomes present in the original cell
messenger RNA (mRNA)	a molecule that serves as a template for protein synthesis
microbe	a microscopic organism; applied particularly to bacteria
microbial mining	a process of extracting minerals with the application of microorganisms
microorganism	an organism too small to be seen with the naked eye (e.g., bacteria, viruses, etc.)
mitosis	a process of nuclear division in eukaryotic cells that produces two progeny cells from one parent cell; each cell is genetically identical to each other
molecular biology	a discipline of science that studies the biochemical and molecular processes of cells, especially the processes of replication, transcription and translation
molecular clock	a tool in the study of molecular evolution that uses fossils and rates of molecular change to deduce the time in geologic history when two species or groups of organisms diverged
multicellular organism	an organism that consists of more than one cell and has differentiated cells that perform specialized functions
nanobiotechnology	a branch of nanotechnology with biological and biochemical applications or uses
nanotechnology	a science of manipulating materials on an atomic or molecular scale
natural selection	a mechanism of evolution by which heritable traits that make it more likely for an organism to survive and successfully reproduce become more common in a population over successive generations
nucleic acid	a macromolecule of nucleotides such as DNA and RNA
nucleotide	a chemical compound (monomer) of nucleic acids
nutraceutical	a substance that may be considered a food or part of a food which provides medicinal or health benefits, including the prevention and treatment of disease
-omics	an approach used in areas of related research that examine sets of molecules (other than DNA) in similar ways
organelle	a specialized structure inside plant and animal cells
organism	any living thing
osmosis	a process of the passage of water or another solvent through a semi-permeable membrane

patent	a legal right, granted by the government of a country, for an owner to exclude others from making, using or selling their invention in that country
phenotype	an observable characteristic or physical appearance of an organism
phospholipid bilayer	a two-layered arrangement of phosphate and lipid molecules that form a cell membrane
phytoremediation	a treatment using plants or algae to clean up polluted water or soil
plasmid	an independent stable, self-replicating piece of DNA in bacterial cells that is not part of the normal bacterial cell genome molecule and does not integrate into the host chromosome
polymerase chain reaction	see *DNA amplification*
prokaryote	a cell or organism lacking a structurally discrete nucleus and other subcellular compartments
protein	a large molecule composed of one or more chains of amino acids in a specific order; proteins are required for the structure and regulation of an organism's cells and tissues; each protein has a unique function
protein synthesis	a process of the transcription and translation of specific parts of DNA to form proteins
proteomics	a study of all the proteins that make up an organism, the way they interact, the changes that they undergo and the effects that they have within the organism
recombinant DNA (rDNA)	a combination of DNA from two different species that are joined using recombinant DNA technologies to form a single molecule
recombinant protein	a protein that is derived from recombinant DNA
restriction enzyme	a protein that recognizes specific, short nucleotide sequences and cuts DNA at those sites
ribonucleic acid (RNA)	a nucleic acid molecule similar to DNA but containing ribose rather than deoxyribose; it assists DNA in controlling protein synthesis in cells
ribosomal DNA (rDNA)	a class of RNA found in the ribosomes of cells
ribosome	a small cellular component composed of specialized ribosomal RNA and protein; site of protein synthesis
selective breeding	see *artificial selection*

stakeholder	a person, group or organization that has a direct or indirect stake in an organization because they can affect or be affected by the organization's actions, objectives and policies
structural protein	a protein that contributes to a cell structure or tissue structure
therapeutics	a branch of medicine that deals specifically with the treatment of disease and the art and science of healing
trademark	a word (or words), a design, or a combination of these, used to identify the goods or services of one person or organization
trait	a genetically determined characteristic
transgenic	a term that describes an organism that has had genes from another organism put into its genome through recombinant DNA techniques
transfer RNA (tRNA)	a class of RNA that has structures with triplet nucleotide sequences that are complementary to the triplet nucleotide coding sequences of mRNA; in protein synthesis, the role of tRNA is to bond with amino acids and transfer them to the ribosomes
unicellular organism	an organism that consists of one cell; they may either be prokaryotes, bacteria and archaea (cells with no nucleus and a simple cell structure) or eukaryotes (which have a nucleus and a more complex cell structure)
viral vector	a modification of viral DNA to serve as a vector for recombinant DNA

Sources:

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