EDUCATIONAL
ACTIVITY KIT

GENETICS AND BIOTECHNOLOGY

Grades 11 and up (Secondary Cycle 2 and up)

How are genetics and biotechnology applied to modern agriculture? What is their impact on the environment?

These inquiry-based activities allow students to investigate the social, ethical and economic consequences of various agricultural innovations, while developing critical-thinking skills.

The activities cover a wide range of topics related to biology, from selective breeding to genetic engineering.

Contents

Ingenium

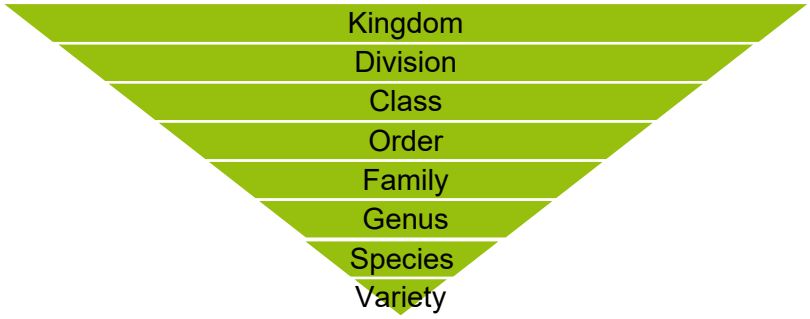
CANADA AGRICULTURE AND FOOD MUSEUM
MUSÉE DE L'AGRICULTURE ET DE L'ALIMENTATION DU CANADA

Canada

Name: _____ Date: _____

ORGANISMS IN A FARMERS'S FIELD—PART I

Taxonomy is the science of classifying organisms using a common naming system. The system gives names to organisms based a set of rules called "taxonomic ranks". These ranks classify species into groups with common characteristics, which become more specific as you move down the hierarchy.



Taxonomy is useful, because it allows scientists to talk in a common and very specific language about living things. For example, if scientists were speaking to one another about "bees", they could be talking about any of 5,700 different species—which can lead to a lot of confusion. However, if these same scientists mention *Bombus hortorum* (Genus *species*) and *Apis mellifera* (Genus *species*), they would both know that they were talking about the garden bumblebee and the domesticated honeybee.

Taxonomy is also used in agriculture by plant breeders and farmers. Before growing a crop in their fields, farmers make choices about what type of crop to grow (species) and its characteristics (variety within the species).

Some varieties may be tolerant to a specific herbicide, or do better in certain soils, or be more resistant to disease, and so forth. For example, a Northern Ontario farmer growing **strawberries** (the species) could plant the varieties **Cavendish** (high-yield, resistant to some diseases, winter-hardy, large dark berries) and/or **Ken** (high-yield, long fruiting season, highly sensitive to disease and hot weather, does well in all soil types, bright-red berries). Both varieties grow well in Northern Ontario, but each has its own characteristics.

Note: You may see the word "cultivar" when looking for varieties. A cultivar is a cultivated variety (a variety grown in fields, rather than in the wild).

Objective

In this activity, you will classify a canola variety grown in a farmer's field.

Understanding Concepts

By analyzing the terminology used in classifying organisms, you will become more familiar with the main taxonomic ranks.

Taxonomy Exercise

Match the terms in the text box with their proper taxonomic rank to come up with the biological classifications of canola.

Brassica napus L.	Capparales	Magnoliophyta
Brassica L.	Plantea	Brassica napus L. subsp. napus	Magnoliopsida
Brassicaceae	Canola	Spring Hybrid VT Desirable

Level of Classification	Common Name of Organism: _____
Kingdom	
Division	
Class	
Order	
Family	
Genus	
Species	
Subspecies	
Variety (cultivar)	

ORGANISMS IN A FARMERS'S FIELD—PART I

Answer Sheet

Match the terms in the text box with their proper taxonomic rank to come up with the biological classifications for four organisms.

Level of Classification	Common Name of Organism: Canola
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Capparales
Family	Brassicaceae
Genus	Brassica L.
Species	Brassica napus L.
Subspecies	Brassica napus L. subsp. Napus
Variety (cultivar)	Spring Hybrid VT Desirable

Name: _____ Date: _____

ORGANISMS IN A FARMER'S FIELD—PART II

In a farmer's field, you will find organisms from every taxonomic Kingdom. Bacteria are the most numerous. They are prokaryotes, and are made up of a single cell. Other organisms—such as plants, animals, and fungi—are made up of eukaryote cells. Eukaryote cells evolved later, and have a more complicated structure than prokaryote cells.

Understanding Concepts

In this activity, you will differentiate cells belonging to four different taxonomic Kingdoms.

Objective

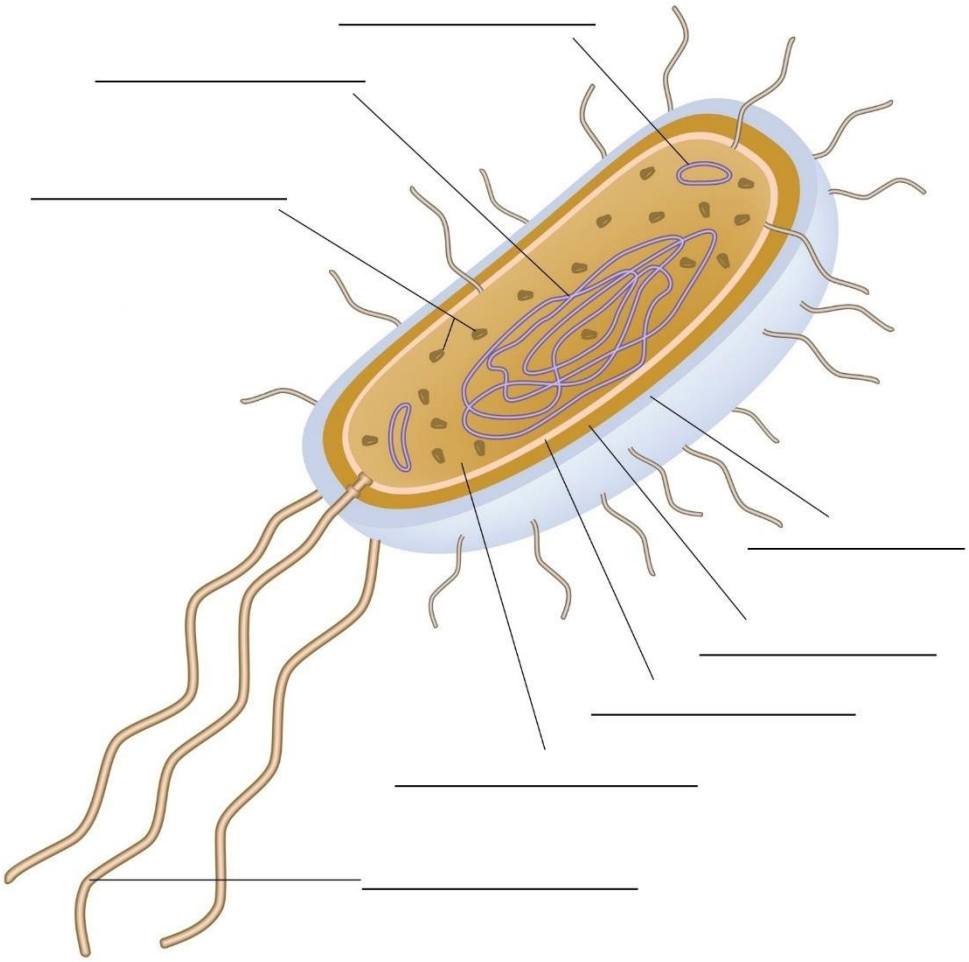
By identifying and labelling the structures of four cells, you will become more familiar with the structures of plant, animal, bacterial and fungal cells.

Exercise in Cell Recognition

Label the cell components in the following four diagrams, using the terms provided below. Indicate whether the diagrams represent a basic animal, plant, bacterial or fungal cell, and why?

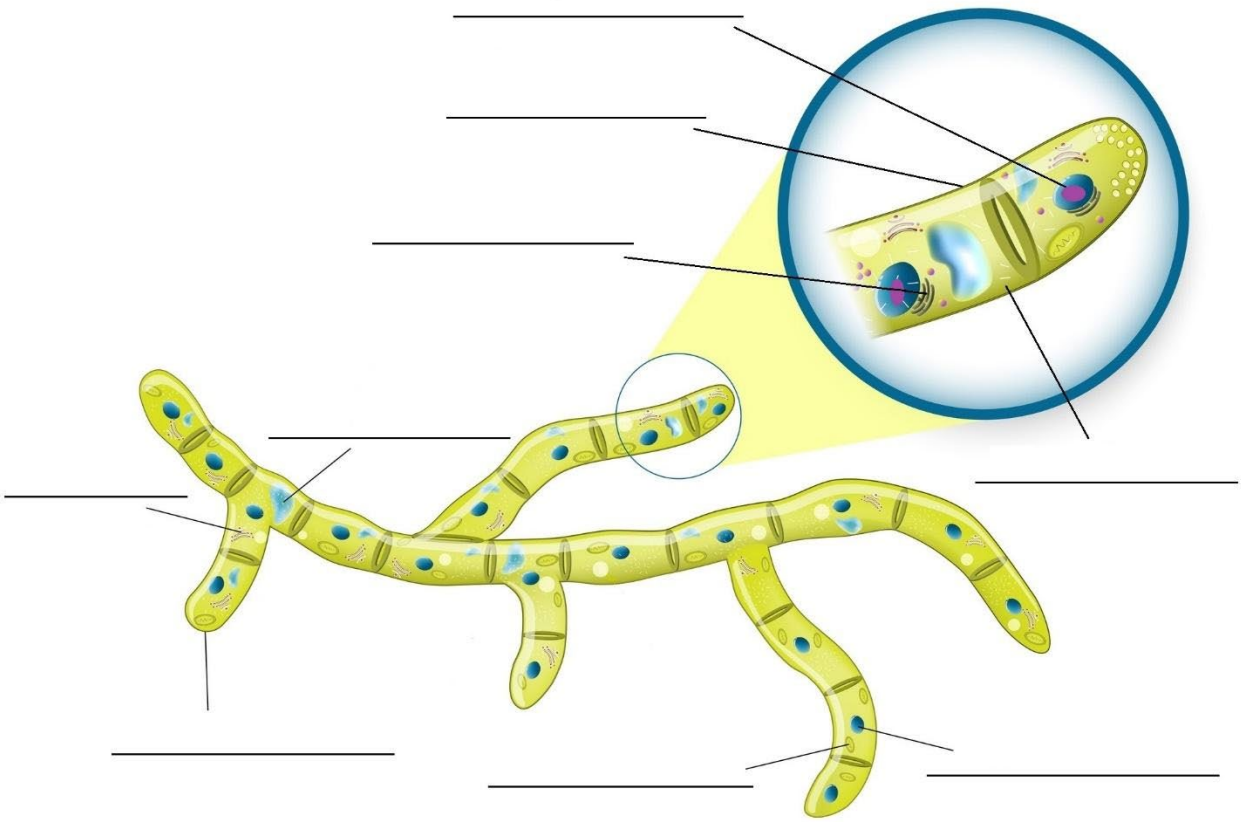
ribosomes	endoplasmic reticulum	cell wall	plasmid DNA
cell membrane	cytoplasm	Golgi apparatus	capsule
nucleus	cell wall	nucleolus	vacuole	flagellum
endoplasmic reticulum	cytoplasm	vacuole	cell membrane
cytoplasm	chromosomal DNA	Golgi apparatus	vacuole
cell wall	endoplasmic reticulum	mitochondrion	chloroplast
nucleolus	ribosome	nucleus	nucleolus	ribosome
mitochondrion	Golgi apparatus	lysosome	nucleus	cytoplasm
cell membrane	cell membrane	mitochondrion	centrosome

_____ CELL



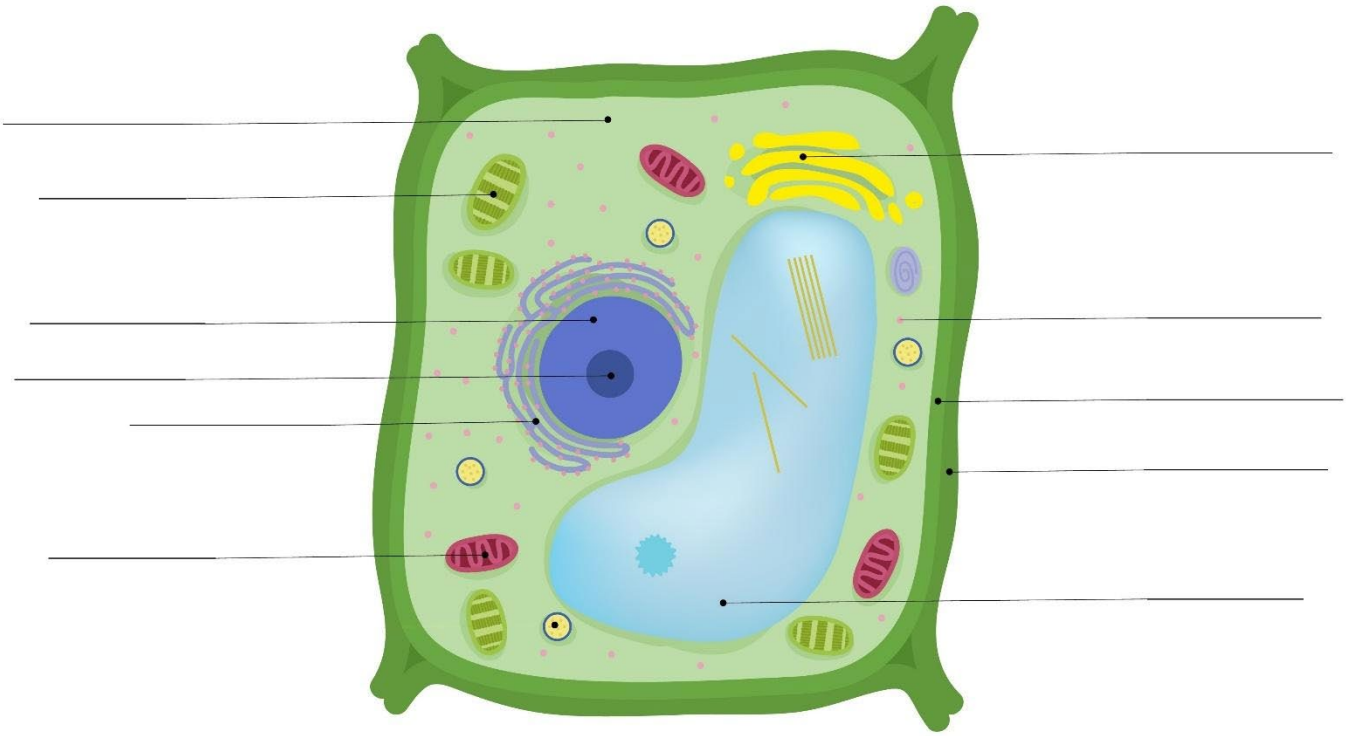
Why?

_____ CELLS



Why?

_____ CELL



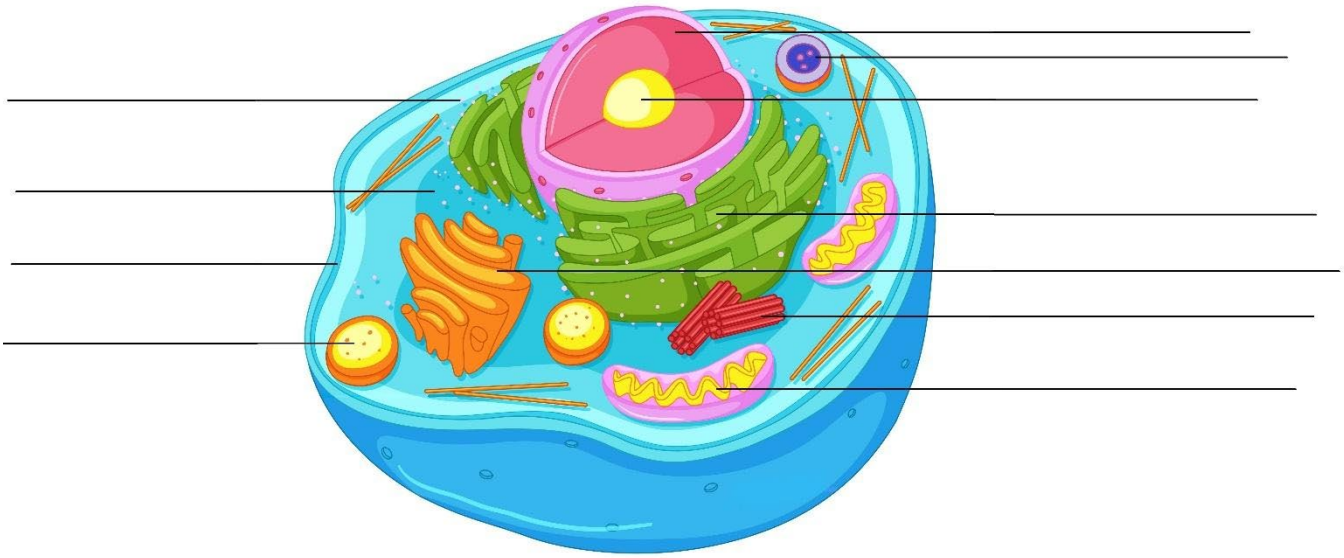
Why?

_____

_____

_____

_____ CELL



Why?

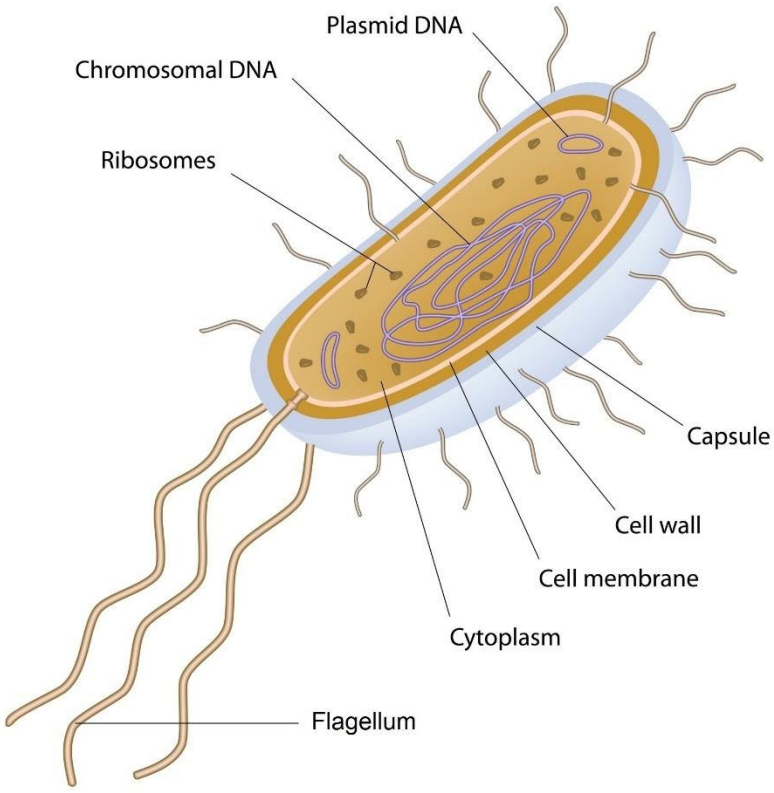
ORGANISMS IN A FARMERS'S FIELD—PART II

Answer Sheet

Exercise in Cell Recognition

Label the cell components in the following four diagrams using the terms provided below. Indicate whether the diagrams represent a basic animal, plant, bacterial or fungal cell, and why.

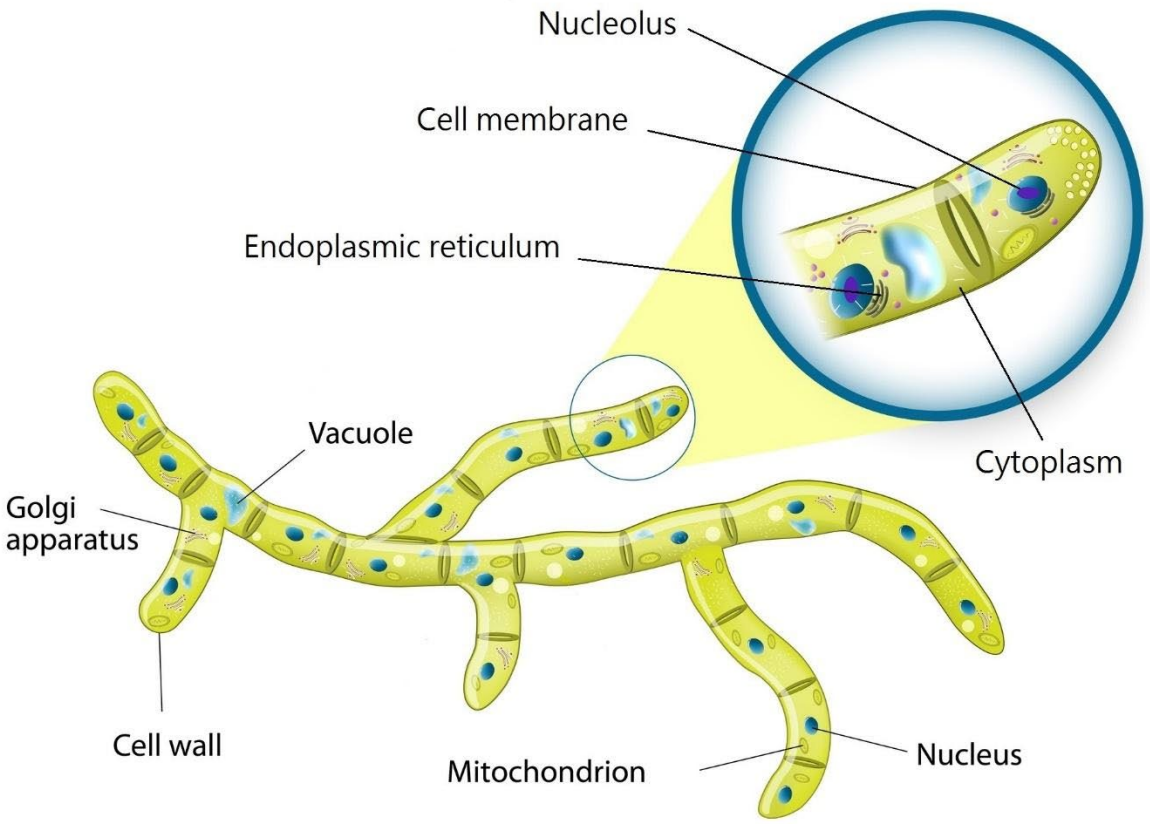
Bacterial Cell



Why?

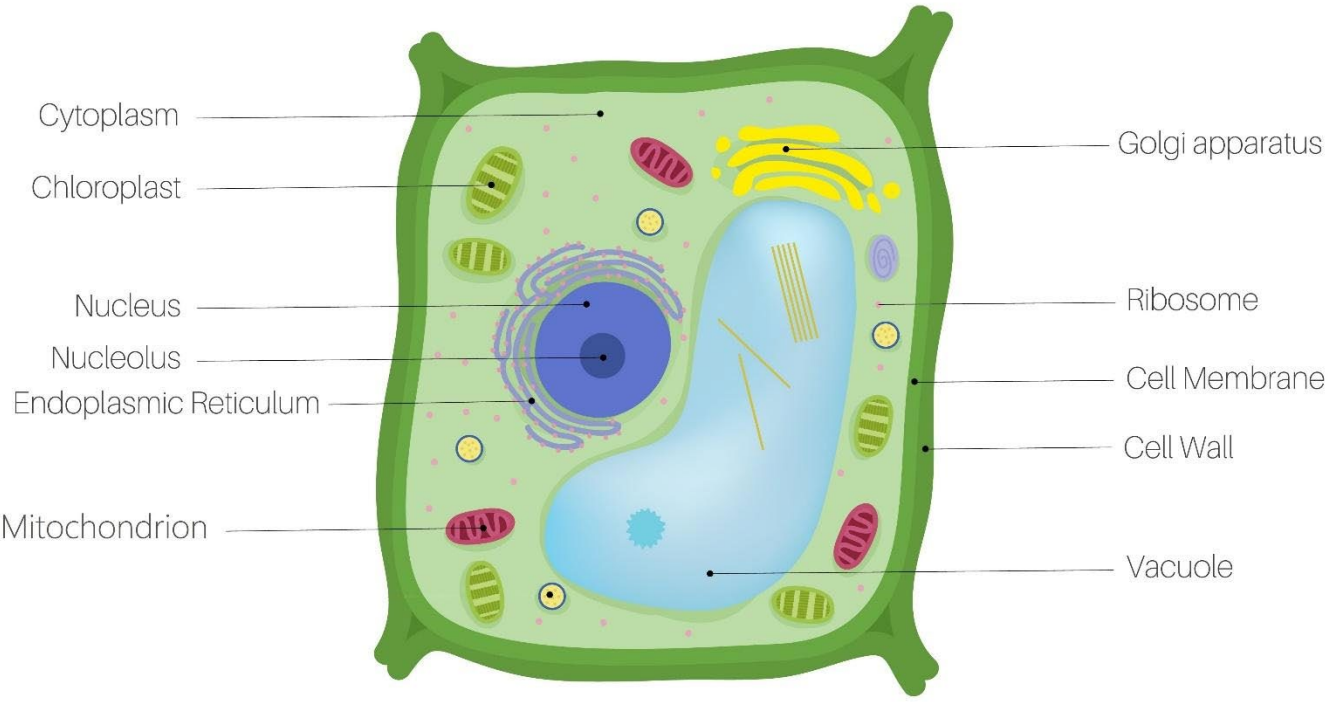
Because it does not have a nucleus, this is a bacterial cell. This prokaryote cell has free-floating DNA (chromosomal and plasmid), and no membrane-bound organelles such as mitochondria.

Fungal Cells



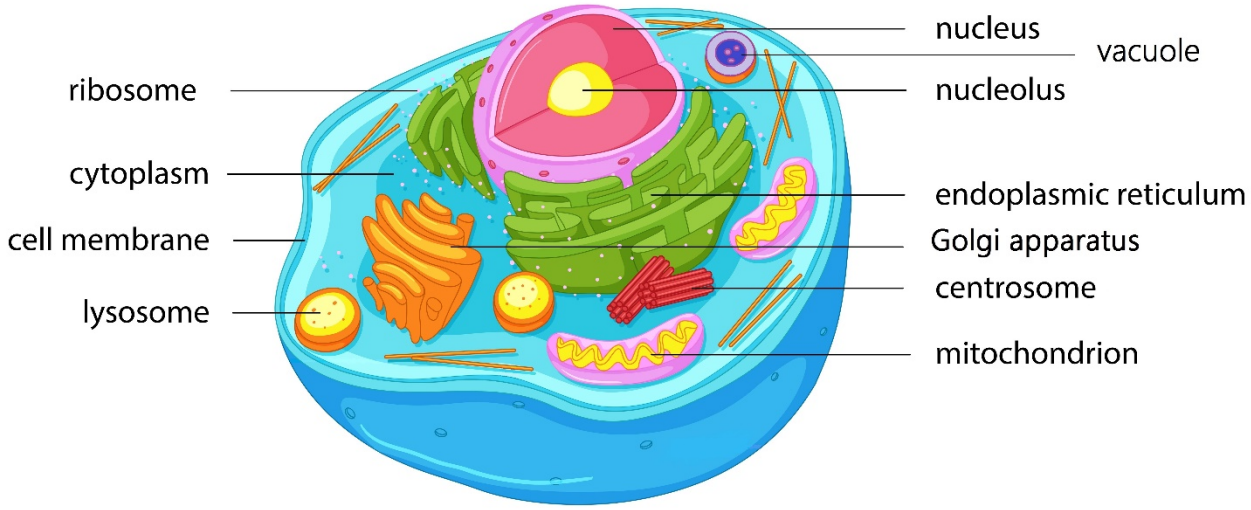
Why?
These are eukaryote cells because their DNA is contained in a nucleus. It is hard to tell at first if these cells are fungal or animal, as the two have very similar structures. The presence of cell walls and large vacuoles indicate, however, that these cells are fungal.

Plant Cell



Why?
The DNA of this eukaryote cell is contained in a nucleus. The presence of chloroplasts indicates that it is a plant cell. The very large vacuole and the cell wall are other indicators.

Animal Cell



Why?
This is a eukaryote cell because its DNA is contained in a nucleus. It is hard to tell if it is a fungal or animal cell, because the two can look very similar. The absence of a cell wall indicates, however, that this is an animal cell.

Name: _____ Date: _____

SOLVING BASIC GENETICS PROBLEMS

Cattle (*Bos Taurus*) have a diploid chromosome number of 60 (29 pairs of autosomal chromosomes—chromosomes that determine individual characteristics—and 1 pair of sex chromosomes). Chromosomes are made up of strands of DNA (deoxyribonucleic acid) wrapped around protein. Individual fixed sections found on these strands—in other words, genes—determine the characteristics of living organisms. Genes are inherited from one generation to the next.

For example, in cattle, genes determine the differences between breeds, including factors such as eye colour, hide colour, milk production, susceptibility to disease, etc. By studying the bovine genome, we can predict the likelihood of cattle inheriting particular traits from its parents. This can help cattle breeders to determine not only the probability of offspring inheriting desirable qualities, but also the chances that they might inherit genetic disorders.

One of the easiest ways to calculate the mathematical probability of the inheritance of a specific gene is the use of a Punnett square. This is a simple graphic way of determining all of the potential combinations of genotypes that can occur in offspring, based on the genotypes of their parents.

The Punnett Square Method

In this activity, you will use the Punnett square method to solve basic genetic problems in cattle.

Objective

By analyzing data to solve basic genetics problems, you will develop your analytical skills and be able to use the appropriate terminology when discussing genetically related conditions.

Questions

1) Hornless dairy cattle, known as "polled cattle", are preferred over horned animals. The growth or lack of horns is controlled by a single gene. The polled gene is "dominant" over the gene that results in horned animals.

   If 50% of the calves born are polled, what was the most probable genetic makeup of their parents? Show your work.

   P = polled (dominant) p = horned (recessive)

2) The Holstein dairy breed has a separate sub-population of animals with a True Red and White coat colour, instead of the traditional Black and White. True Red and White coat colour is controlled by a single gene. The two forms of this gene (alleles) are labelled as "B=black" and "r=red", which means that an animal can only have a True Red and White coat colour when it carries two copies of the red gene (rr: double-recessive).

   If a dairy farmer breeds a bull with a True Red and White coat (rr) to a cow that is homozygous for a Black and White coat (BB), what ratio of coat colours (phenotypes) would you expect in the calves. Show your work.

   A) 3 B : 1 r B) 4 B : 0 r C) 2 B : 2 r D) 1 B : 3 r

3) Most genetic anomalies in dairy cattle are controlled by genes that are recessive rather than dominant. For genetic recessives, only homozygous animals, which have inherited two copies of the gene, are affected. Heterozygous animals—animals with copies of various genes—are usually referred to as "carriers". Bovine Leucocyte Adhesion Deficiency (BLAD) is an recessive congenital disease controlled by a single gene. Affected calves suffer from stunted growth, recurrent infections such as pneumonia, slow wound-healing, and they will generally die within their first year.

   If a dairy farmer breeds a bull that is a carrier of the BLAD gene (Bb) to a cow that is also a carrier (Bb), what percentage of the calves will be affected? Show your work.

   A. 75% B. 0% C. 100% D. 25%

4) If a bull and a cow that are both heterozygous polled and carriers for BLAD (genotype PpBb) are mated, what percentage of the calves will be carriers for BLAD? Show your work.

5) A few inherited defects are known to be caused by genes with incomplete dominance. Lethal chondrodysplasia (bulldog syndrome) is a well-known congenital syndrome in cattle, and shows up from time to time in many breeds. With advances in molecular genetics, ways of identifying genetic causes of such syndromes have improved significantly. In a few instances, gene mutation has caused lethal chondrodysplasia. These mutations showed incomplete dominance, leading to a mild form of the disease in heterozygous animals (C^1C), while homozygous animals (C^1C^1) usually died during gestation.

   If a cow aborts a fetus with a severe form of the disease, what was the most likely genetic makeup of the parents? Show your work.

6) A few inherited defects are caused by two or more sets of genes. Polydactyly is a relatively rare genetic disease found in dairy and beef cattle. One or both front hooves are affected, but sometimes in all four hooves the outer dew claw develops into an extra toe. At least two sets of genes are involved in inheritance of this trait. Inheritance is thought to require a dominant gene at one locus (Aa), and two recessive genes at another locus (bb).

   If the following two animals are mated, what percentage of their calves will be affected by Polydactyly? Show your work.

   cow (AaBb) x bull (aabb)

SOLVING BASIC GENETIC PROBLEMS

Answer Sheet

1) If 50% of the calves born are polled, what was the most probable genetic makeup of their parents? Show your work.

P = polled (dominant) p = horned (recessive)

Option 1: One parent could be PP, and the other could be Pp:

	P	P
P	PP	PP
p	Pp	Pp

If both parents have one or both dominant polled genes, the calves can only be polled. This means that the parents ***cannot be PP and Pp.***

Option B: Both parents could be Pp:

	P	p
P	PP	Pp
p	Pp	pp

This is not *the most probable makeup of the parents, since 75% of the calves are likely to be polled.*

Option B: One parent could be Pp, and the other could be pp:

	P	p
p	Pp	pp
p	Pp	pp

Two calves have the dominant gene and are polled, while the other two calves are horned. Therefore, Pp and pp ***is the most probable genetic makeup of the parents.***

2) If a dairy farmer breeds a bull with a True Red and White coat (rr) to a cow that is homozygous for a Black and White coat (BB), what ratio of coat colours (phenotypes) would you expect in the calves. Show your work.

A) 3 B : 1 r B) 4 B : 0 r C) 2 B : 2 r D) 1 B : 3 r

rr x *BB*

Bull with True Red and White coat colour — *Cow with Black and White coat colour*

	r	*r*
B	*Br*	*Br*
B	*Br*	*Br*

All four calves carry the dominant gene (B) for Black and White coat colour. Therefore, the expressed phenotypic ratio of their calves is 4 B : 0 r.

3.) If a dairy farmer breeds a bull that is a carrier of the BLAD gene (Bb) to a cow that is also a carrier (Bb), what percentage of the calves will be affected? Please show your work.

A. 75% B. 0% C. 100% D. 25%

Bb x *Bb*

Carrier bull — *Carrier cow*

	B	*b*
B	*BB*	*Bb*
b	*Bb*	*bb*

Only one calf carries both recessive genes for BLAD. Therefore, 25% of all calves born are likely to be affected by BLAD.

4) If a bull and a cow that are both heterozygous polled and carriers for BLAD (genotype PpBb) are mated, what percentage of the calves will be carriers for BLAD? Show your work.

A. 50% B. 0% C. 25% D. 75%

Possible gametes from the parents: PB, Pb, pB and pb.

	PB	Pb	pB	pb
PB	PPBB	PPBb	PpBB	PpBb
Pb	PPBb	PPbb	PpBb	Ppbb
pB	PpBB	PpBb	ppBB	ppBb
pb	PpBb	Ppbb	ppBb	ppbb

Eight out of sixteen calves (8/16 = ½) are carriers for BLAD. Therefore, 50% of the calves will be carriers for BLAD.

5) If a cow aborts a fetus with a severe form of lethal chondrodysplasia, what was the most probable genetic makeup of the parents? Show your work.

C = normal gene *C¹ = mutated gene*

Both parents cannot be homozygous for the mutated gene (C¹C¹), since it's a lethal condition. One parent could be C¹C, and the other CC:

	C¹	C
C	CC¹	CC
C	CC¹	CC

Two calves are carriers and two calves are non-carriers. This is not the most probable makeup of the parents, because none of the offspring are homozygous for the mutated gene.

Both parents could have one copy of the mutated gene C¹C:

	C¹	C
C¹	C¹C¹	CC¹
C	CC¹	CC

One calf is affected, two are carriers, and one is a non-carrier. Therefore, the most probable genetic makeup of the parents is C¹C and C¹C.

6) If the following two animals are mated, what percentage of calves will be affected by Polydactyly? Show your work.

Cow (AaBb) x Bull (aabb)

The possible gametes from the parents: (1) AB, Ab, aB and ab; (2) ab, ab, ab and ab.

	AB	*Ab*	*aB*	*ab*
ab	*AaBb*	*Aabb*	*aaBb*	*aabb*
ab	*AaBb*	*Aabb*	*aaBb*	*aabb*
ab	*AaBb*	*Aabb*	*aaBb*	*aabb*
ab	*AaBb*	*Aabb*	*aaBb*	*aabb*

Four out of sixteen calves (4/16 = ¼) are affected by Polydactyly. Therefore, 25% of the calves will be affected by Polydactyly.

CANOLA: A CANADIAN INNOVATION

More than fifty years ago, Canadian plant researchers took on a challenge: to create a healthy vegetable oil from rapeseed, a little-known plant that grew well on the Prairies. Following decades of collaboration and hard work, scientists succeeded in developing one of Canada's most important crops—canola.

Canola is used to produce cooking oil, animal feed, biofuel, and more. It belongs to the Brassicaceae family, which also includes turnips, kale, and mustard.

Research Assignment

In this activity, you will research and illustrate, in a graphic novel, the factors that led to the development of canola in Canada between the 1940s and 1970s.

Objective

By examining and illustrating the story behind canola, you will identify a variety of careers related to science, while also underscoring the contributions made by Canadian scientists.

Canola: A Graphic Novel

Starting with the resources listed below, you will research the conditions brought on by the Second World War that created a need for the domestic production of rapeseed. You will then examine why there was a push in the Prairie Provinces for an alternative crop that produced edible oil and animal meal.

By exploring the research of scientists in Saskatoon, you will discover the technological advances that enabled scientists to develop canola from rapeseed. You will illustrate your findings in a graphic novel. You must supply a list of resources supporting the facts presented in your graphic novel.

Resources

https://wdm.ca/wp-content/uploads/2018/08/WDM-CanolaResearchPaper.pdf
https://www.canolacouncil.org/canola-encyclopedia/crop-development/history-of-varietal-development/
http://www.thecanadianencyclopedia.ca/en/article/canola/
http://www.statcan.gc.ca/pub/96-325-x/2007000/article/10778-eng.htm
https://www.canada.ca/en/news/archive/2007/08/canada-takes-lead-canola-research.html

CHEESEMAKING—ENZYMES AT WORK: LABORATORY ACTIVITY

Cheesemaking is one of the earliest examples of biotechnology—in this case, using a living organism or biological process to create or modify a product. The art of cheesemaking dates back millennia to the domestication of goats, cows, sheep and buffalo for milk. Today, cheesemaking is an important Canadian domestic and export industry that depends on bacteria, mold, and enzymes.

Cheesemakers use bacteria, enzymes, and even mold to produce cheese. Lactic acid bacteria are used to acidify milk by converting lactose to lactic acid. Other good microbes can be added to flavour the cheese as it ripens. White molds (in particular *Penicillium camemberti*) are responsible for the aroma and texture of brie and camembert, while blue molds (*Penicillium roqueforti* and *Penicillium glaucum)* are responsible for blue cheeses.

Rennet enzymes (chymosin, pepsin, and lipase) are used for one of the basic steps in cheesemaking, called "curdling". This involves separating the milk into curds (solids) and whey (liquid). Rennet coagulation involves adding animal rennet, vegetable rennet, or chymosin to milk.

Ingenium

CANADA AGRICULTURE AND FOOD MUSEUM
MUSÉE DE L'AGRICULTURE ET DE L'ALIMENTATION DU CANADA

Canada

Laboratory Investigation

In this laboratory investigation, you will evaluate the coagulating properties of different enzymes on the milk protein casein.

Objective

You will expand your laboratory and critical thinking skills by developing an experiment in which you compare the coagulating properties of animal rennet, vegetable rennet, and chymosin when added to cow's milk.

Developing a Laboratory Experiment

You must plan an experiment to compare the coagulating properties of animal rennet, vegetable rennet, and chymosin when added to cow's milk. You must first research these three substances to familiarize yourself with their characteristics. These coagulating enzymes should be available through the following Canadian website: www.makecheese.ca. The website also features a Fresh Mozzarella recipe that can theoretically be prepared in an hour. Your personal experiment report should include:

- Background information on animal rennet, vegetable rennet, and chymosin
- Question and hypothesis
- List of materials
- Experimental procedure (include all the steps you went through to complete the experiment—anyone should be able to replicate your experiment)
- Results of the experiment (you will need to find a way to quantify your data and display it in an appropriate format)
- Conclusions (restate hypothesis and question, draw conclusions based on data, and list any procedural changes you would make if doing the experiment again)

BT CORN AND RECOMBINANT DNA TECHNOLOGY

One of the key factors influencing crop yields is the presence of pests and diseases. A pest is any unwanted harmful organism, such as an insect, weed, rodent, bacterium, fungus, etc. Some insects, for instance, have a direct impact on food production by chewing the leaves of crop plants, boring into the roots, stems or leaves, or spreading plant pathogens.

Plant breeders have been successful in producing a few insect-resistant cultivars (varieties) of some crops through conventional breeding. Recombinant DNA technology, however, has allowed plant breeders to take a specific gene (or genes) from another organism and splice it directly into a plant's genome to make it resistant to a specific pest. In the case of Bt corn, the transgenic corn plant was modified to produce an insecticidal protein that occurs naturally in the bacterium *Bacillus thuringiensis* (Bt).

Understanding Concepts

In this activity, you will research how plant breeders developed Bt corn using recombinant DNA technology, and will showcase your findings in a multimedia presentation.

Objective

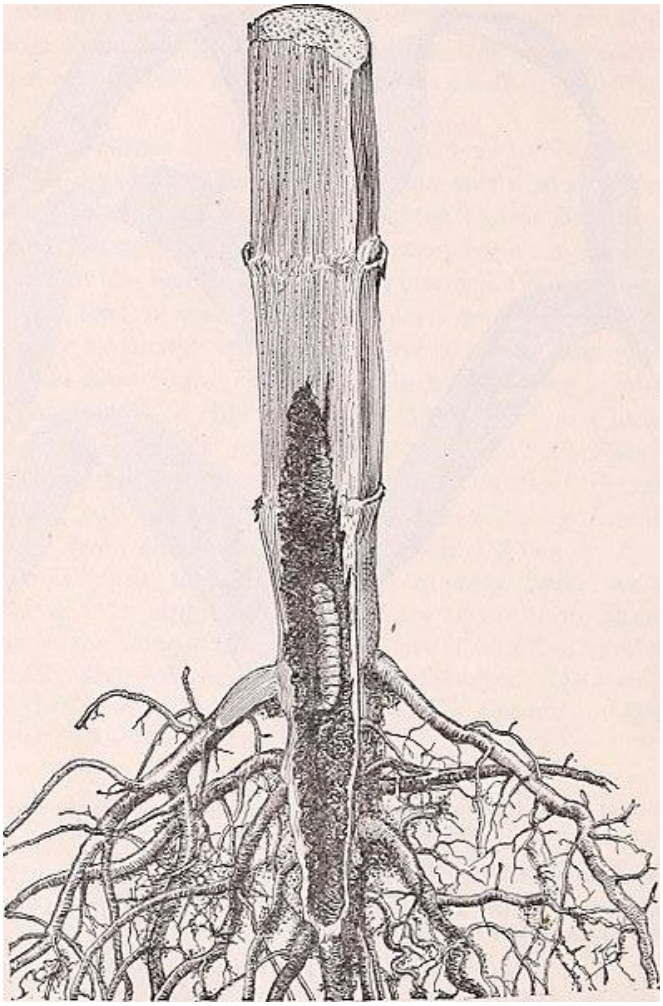
By researching and presenting how this insect-resistant crop was developed, you will gain a better understanding of how genetic engineering is applied to agriculture.

Research Exercise

Investigate the properties of the soil bacterium *Bacillus thuringiensis* (Bt), and why plant breeders transferred genetic material from this organism into corn. Study the steps involved in recombinant DNA technology for plants, and how these steps were applied in the development of Bt corn (which is resistant to the European corn borer). Write down your findings.

Multimedia Presentation

A multimedia presentation uses a combination of different content formats such as text, audio, images, animations, video and interactive content. In your multimedia presentation, you will be presenting your findings on the soil bacterium *Bacillus thuringiensis* (Bt), along with the steps involved in developing Bt corn. You can present your findings from one of the following perspectives:



- The plant breeder who developed Bt corn
- The farmer who grows Bt corn in his field
- The farmer who does not grow Bt corn in his field
- The corn plant that was genetically engineered
- The journalist who first reported the scientific achievement
- The time-traveller who happened upon this agricultural breakthrough
- The environmentalist

Although a multimedia presentation can be playful and humorous in tone, you must still convey your findings in an objective manner.

BT CORN AND RECOMBINANT DNA TECHNOLOGY

Answer Sheet

Research Exercise

Investigate the properties of the soil bacterium *Bacillus thuringiensis* (Bt), and why plant breeders transferred genetic material from this organism into corn. Study the steps involved in recombinant DNA technology for plants, and how these steps were applied in the development of Bt corn (which is resistant to the European corn borer). Write a summary of your findings.

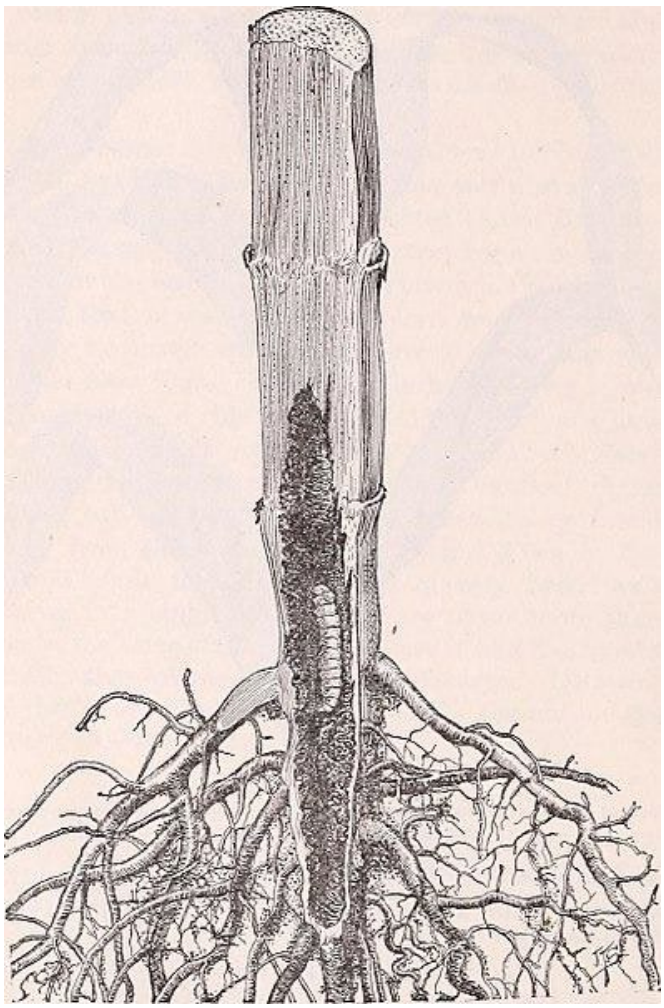
Some strains of the soil bacterium Bacillus thuringiensis *(Bt) produce proteins that are toxic to certain insects with alkaline digestive tracts. These strains of the bacterium produce crystal delta-endotoxins—called Cry proteins, for short—that are toxic to moths and butterflies (Lepidopterans). When their caterpillars ingest the Cry proteins, the proteins are activated by their digestive enzymes. The proteins bind to cells in the lining of the gut wall, and rupture them. Eventually, the insect dies of septicemia.*

Scientists identified a strain of Bt toxic to the European corn borer (a moth) and isolated the gene responsible for production of the lethal Cry protein. They first cut the "gene of interest" from the Bt genome with the help of restriction enzymes. When a restriction enzyme comes into contact with a DNA sequence with a shape matching part of the enzyme—called a "recognition site"—it wraps around the DNA and causes a break in both strands of the DNA molecule.



To transfer a gene of interest into a plant, the gene is inserted into a plant cell using an artificial chromosome called a "vector". Most vectors are based on plasmids, which are small circular sequences of DNA that occur naturally within bacteria, and can replicate independently of the bacteria. The Ti (tumour-inducing) plasmid from the bacterium Agrobacterium tumefaciens *is used as a vector in biotechnology.*

Scientists cut the circular DNA sequence of the Ti plasmid vector with the help of restriction enzymes, and incorporated the gene of interest from the Bt genome into the plasmid, using a bacterial enzyme called "DNA ligase". The recombinant DNA molecule also has a promoter sequence in front of the gene of interest, which gives the plasmid instructions on where and how much of the desired Cry protein to express. Scientists also added a genetic marker to identify "successful transformation"—when a gene adds resistance to a chemical, such as an antibiotic or herbicide.



Scientists then reintroduced the recombinant Ti plasmid vector into Agrobacterium tumefaciens *cells by creating tiny holes within the bacterial cell membranes. This can be done by suddenly heating the bacterial culture by several degrees, or by passing an electrical shock through the culture. The genetically engineered* Agrobacteria tumefaciens *are then cultured in bioreactors. As the bacteria replicate, the recombinant DNA molecules are replicated along with the host DNA. Scientists will then infect corn plants with the recombinant*

Agrobacterium tumefaciens, *which will deliver the recombinant Ti plasmid vectors to plant cells, causing them to express a recombinant form of the Cry protein.*

A CASE STUDY: THE ENVIRONMENTAL IMPACT OF BT CORN

The European corn borer (ECB), *Ostrinia nubilalis*, is one of the most destructive insect pests of corn in Canada. The ECB is a moth larva that bores into the stalks and ears of corn and other host plants.

The ECB overwinters in corn stalks and other crop residue left in fields. Farmers can reduce the quantity of overwintering ECB in their corn fields by ploughing under the crop residue (turning the soil).

If the ECB survives the winter and continues its lifecycle, farmers can choose to control the pest by spraying the corn crop with a liquid insecticide, such as one containing *Bacillus thuringiensis* (*Bt*). Farmers can also control the pest by planting Bt corn (a transgenic corn plant engineered to produce an insecticidal protein that occurs naturally in the soil bacterium *Bacillus thuringiensis*).

The appearance of Bt corn on Canadian farms since the 1990s has raised questions regarding the environmental impact of this transgenic crop.

Critical Thinking

In this activity, you will analyze five written texts pertaining to the environmental impact of Bt corn. You will then write your own objective analysis based on these texts.

Please note: The terms "environmental impact" refer both to the negative implications and beneficial aspects of this subject.

Objective

By developing your own argument on the environmental impact of Bt corn, you will develop critical reading and thinking skills, as well as a better understanding of this particular transgenic crop, and its use on Canadian farms.

Ingenium

CANADA AGRICULTURE AND FOOD MUSEUM
MUSÉE DE L'AGRICULTURE ET DE L'ALIMENTATION DU CANADA

Canada

Analysis of Texts

To help develop your critical thinking and reading skills, you will first read two articles developed for students at the University of Toronto: "*Critical Reading Toward Critical Writing*" and "*Research Using the Internet.*" Using the recommendations in these two articles, you will analyze the following written text: "*Use and Impact of Bt Maize*" (2012) by Richard L. Hellmich and Kristina Allyse Hellmich in *Nature Education Knowledge* 3(10):4.

Again using the recommendations provided in the articles above, you must find and analyze four additional written texts pertaining to the environmental impact of Bt corn, using both Internet and library resources. Based on your critical reading of all five texts, you will write your own critical analysis of the environmental impact of Bt corn, citing sources supporting your argument.

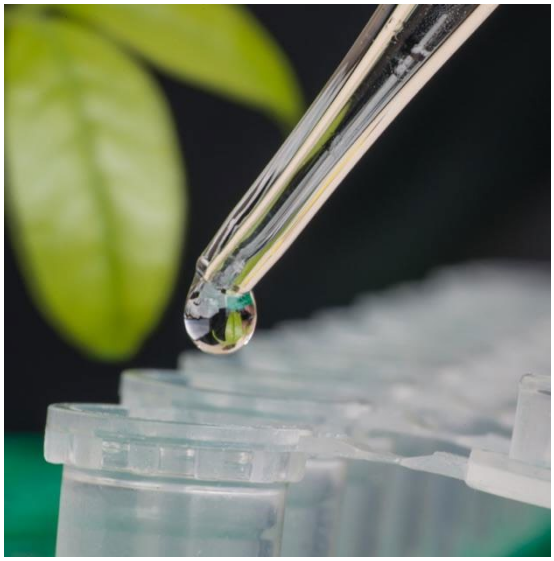
Resources

http://advice.writing.utoronto.ca/researching/critical-
http://advice.writing.utoronto.ca/researching/research-using-internet/
http://nature.com/scitable/knowledge/library/use-and-impact-of-bt-maize-46975413

Corn destruction caused by European corn borer.

Courtesy of Agronom / Wikimedia Commons

CANOLA AND BIOTECHNOLGY: RESEARCH OF PLANT-BREEDING TECHNIQUES



All domesticated plants and animals are genetically modified organisms (GMO)—in other words, they are the result of human intervention. Over thousands of years, we have selected and bred animals and plants based on the characteristics we want and need. This process has resulted in a wide variety of plants and animals that would not otherwise exist.

This form of genetic manipulation is called selective breeding (or conventional breeding). For the longest time, it was the only technique available to create new varieties of plants, although other plant-breeding techniques have since been developed. Plant breeders can now use techniques such as mutagenesis, recombinant DNA, and genome editing.

Understanding Concepts

In this activity, you'll research various plant-breeding techniques used by scientists to develop canola varieties.

Objective

By closely examining conventional plant breeding, mutagenesis, recombinant DNA and genome-editing techniques, you will gain a better understanding of how genetic engineering is used in agriculture.

Group Work

The class will be divided into at least four groups. Each group will research one of the questions below, and present its findings to the class.

Ingenium

CANADA AGRICULTURE AND FOOD MUSEUM
MUSÉE DE L'AGRICULTURE ET DE L'ALIMENTATION DU CANADA

Canada

Articles

Use the following articles as a starting point for your research:

- https://www.biofortified.org/info/graphic-en/crop-modification-techniques/
- https://www.canolacouncil.org/canola-encyclopedia/crop-development/history-of-varietal-development/
- http://www.monsantoglobal.com/global/au/products/Documents/tech-topic-what-is-roundup-ready-canola.pdf
- https://www.canada.ca/en/health-canada/services/food-nutrition/genetically-modified-foods-other-novel-foods/approved-products/novel-food-information-imidazolinone-tolerant-clearfield-canola-quality-brassica-juncea-s006.html
- https://www.canada.ca/en/health-canada/services/food-nutrition/genetically-modified-foods-other-novel-foods/approved-products/truflex-trade-roundup-ready-canola-88302.html
- https://www.canada.ca/en/news/archive/2007/08/canada-takes-lead-canola-research.html
- https://www.canada.ca/en/news/archive/2011/08/announcements-major-piece-canola-genome-puzzle-solved.html

Please note: You are not likely to find articles that directly describe how the following varieties of canola were developed. You must research the methodology behind each plant-breeding technique, and hypothesize how the canola varieties were developed.

Questions

1. In 1974, the world's first canola cultivar—the *Brassica napus* variety Tower—was registered. This Canadian innovation was achieved through conventional plant breeding by crossing low-glucosinolate *Brassica napus* variety Bronowski with a low-erucic-acid *Brassica napus* cultivar such as Oro. Explain the steps involved in the development of this variety, and its significance to the history of canola.
2. In 1995, the first herbicide-tolerant canola—tolerant to the herbicide imidazolinone—was registered: the *Brassica napus* variety Clearfield 45A71. This variety was developed through induced mutagenesis. Explain the steps involved in the development of this variety.
3. In 1995, the first transgenic *Brassica napus* variety tolerant to glyphosate—the active ingredient in Roundup®-brand herbicides—was registered. Plant breeders developed this variety by using recombinant DNA techniques. Explain the steps involved in the development of this variety.

4. *Genome editing is a new way of altering a plant's genome. It employs "molecular scissors" to alter a gene in a plant's DNA, without introducing foreign genes. One example of "molecular scissors" is the CRISPR-Cas9 system. Explain the steps involved in genome editing with this system, and its benefits and limitations for plant breeders.*

CANOLA AND BIOTECHNOLGY: RESEARCH OF PLANT-BREEDING TECHNIQUES

Answer Sheet

Questions

1. In 1974, the world's first canola cultivar—the *Brassica napus* variety Tower—was registered. This Canadian innovation was achieved through conventional plant breeding by crossing low-glucosinolate Brassica *napus* variety Bronowski with a low-erucic-acid Brassica *napus* crop cultivar such as Oro. Explain the steps involved in the development of this variety, and its significance in the history of canola.

   The original rapeseed varieties all produced seeds that contained high amounts of erucic acid (in the oil), and high amounts of glucosinolates (in the meal). Initially, scientist bred a line of rapeseed low in erucic acid, using the Brassica napus *variety Liho as a parent. Liho had the desired low-erucic-acid genetic trait. Plant breeders crossed Liho with other rapeseed varieties well adapted to the Canadian Prairies, then selected and isolated descendants that had inherited the desired low-erucic-acid trait. The first low-erucic-acid* Brassica napus *cultivar to be developed was Oro.*

   Researchers then travelled the world in search of a rapeseed varieties low in glucosinolates (the second desired trait). They found it in the Brassica napus *variety Bronowski. Plant breeders then crossed newly developed low-erucic-acid varieties with plants from the Bronowski variety that had the desired low-glucosinolates trait. By testing and selecting plants that inherited both desired traits, they produced a new cultivar of rapeseed low in both erucic acid and glucosinolates.*

   The cross-breeding was done manually, since Brassica napus *varieties are self-pollinating. They first had to remove the male organs of the flower in the female parent of the cross. Once the source of pollen grains was removed, the plant could not fertilize itself. The plant breeder then deposited—most likely with the help of a brush—pollen from the selected male parent into the female part of the flower of the female parent. For several years, plant breeders kept selecting and crossbreeding among the descendants of these crosses for plants that had inherited the two desired characteristics.*

   Seeds were selected and field-tested before the variety was registered by the Canadian Food Inspection Agency, and approved by Health Canada for human consumption. It could be grown for human consumption of its seed oil, and consumption of its seed meal by animals.

*To distinguish the new "double-low" cultivar from other rapeseed, the Western Canadian Oilseed Crushers Association coined the name "**canola**". It is a combination of the words "Canada" and ola, which derives from the Latin word for "oil." It is also an acronym for "**Can**adian **O**il **L**ow **A**cid.". The official definition of canola in the Canadian* Feeds Act *and* Seeds Act *is: "An oil that must contain less than 2% erucic acid, and less than 30 micromoles of glucosinolates per gram of air-dried oil-free meal."*

2. **In 1995, the first herbicide-tolerant canola—tolerant to the herbicide imidazolinone—was registered: the *Brassica napus* variety Clearfield 45A71. This variety was developed through induced mutagenesis. Explain the steps involved in the development of this variety.**

   With induced mutagenesis, plant breeders provoke changes or "mutations" in the genome of a target species, without adding DNA from another organism. Various chemicals and ionizing radiation can be used to induce these changes. Brassica napus *variety 45A71 was developed from microspores of the Brassica* napus *variety Topas. Microspores are highly specialized haploid cells (i.e., having half the usual number of chromosomes, since they are produced from reproductive cells or gametes). Microspores are immature pollen cells, rather than fully developed pollen grains.*

   The microspores of the Brassica napus *variety Topas were isolated from the donor plants before the flower buds opened. Plant breeders dipped thousands of microspores in a solution of ethylnitrosourea, a mutagen solution. In some microspores, exposure to this chemical caused a mutation within the acetolactate synthase (ALS) encoding gene. This resulted in the enzyme becoming insensitive to the activity of the herbicide imidazolinone. The mutated microspores were then regenerated into plants through tissue culture. The microspores were forced in vitro to double their DNA and develop into embryos.*

   Plant breeders selected the microspores with the desired traits by dipping the embryos into a solution that contained the imidazolinone herbicide. Plant breeders then grew the embryos that survived the process. Seeds were selected and field-tested before the variety was registered by the Canadian Food Inspection Agency and approved by Health Canada for human consumption.

   Clearfield 45A71 allows farmers to use imidazolinone herbicides (those that contain the active ingredient imidazolinone) for weed control. Imidazoline herbicides do not kill the Clearfield 45A71 canola crop, but destroy all other plants growing in that same field (i.e., weeds).

   Because it does not contain any foreign genes, the canola variety Clearfield 45A71 is not transgenic, nor is it considered "genetically engineered".

3. In 1995, the first transgenic *Brassica napus* variety tolerant to glyphosate—the active ingredient in Roundup®-brand herbicides—was registered. Plant breeders developed this variety by using recombinant DNA techniques. Explain the steps involved in the development of this variety.

   Recombinant DNA techniques allow the direct transfer or removal of genes from an organism. That organism is then considered to have been "genetically engineered" or transgenic. To produce Roundup Ready® canola, scientists introduced two genes into the canola genome.

   Specialized restriction enzymes were used to "cut" or remove the genes coding for protective enzymes (enzymes that make the plant tolerant to the herbicide). When a restriction enzyme comes into contact with a DNA sequence having a shape that matches part of the enzyme—called a "recognition site"—it wraps around the DNA and causes a break in both strands of the DNA molecule.

   The genes coding for protective enzymes were taken from the following organisms:

   - *The cp4 epsps gene, derived from the common soil bacterium* Agrobacterium strain CP4, *which encodes for production of the CP4 EPSPS enzyme.*
   - *The gox gene from* Ochrobactrum anthropi strain LBAA, *which encodes for production of the enzyme glyphosate oxidase (GOX).*

   The two genes provide tolerance to glyphosate, the active ingredient in the Roundup® family of herbicides.

   The genes were introduced to the Brassica napus *plant using an artificial chromosome called a "vector". Most vectors are based on plasmids, which are small circular sequences of DNA that occur naturally within bacteria, and that can replicate independently of the bacteria.*

   In nature, the Agrobacterium tumefaciens *is a plant pathogen. It infects a plant through its Ti plasmid, which causes the development of crown gall disease. Plant breeders used a modified Ti plasmid vector to develop the herbicide-tolerant variety of canola: one from which a disease-causing segment of DNA was removed, and replaced with the two genes carrying the desired traits (in this case, herbicide tolerance). Scientists cut the circular DNA sequence of the Ti plasmid vector using restriction enzymes, then incorporated the genes of interest (tolerance) into the plasmid vector by sticking together the ends of the genes and the opened vector with a bacterial enzyme called DNA ligase.*

   Scientists then reintroduced the recombinant Ti plasmid vector into Agrobacterium tumefaciens *cells by creating tiny holes in the bacterial cell membranes. This can be done by suddenly heating the bacterial culture by several degrees, or by passing an electrical shock through the culture. The genetically engineered* Agrobacterium tumefaciens *are then cultured in bioreactors. As the bacteria replicate, the recombinant DNA molecules are replicated along with the host DNA.*

The genetically engineered Agrobacteria tumefaciens *were then introduced to Brassica* napus *plant cells, where they were allowed to infect the plant cells, incorporating the new herbicide-tolerant genes with the desired traits into the plant's genome. The* Brassica napus *plants grown from these genetically engineered plant cells are tolerant of glyphosate, because the plant now produces the two protective enzymes within its own tissues. Seeds were selected and field-tested before the variety was registered by the Canadian Food Inspection Agency and approved by Health Canada for human consumption. Roundup Ready® canola allows farmers to use Roundup for weed control in fields containing this variety.*

4. **Genome editing is a new way of altering a plant's genome. It employs "molecular scissors" to alter a gene in a plant's DNA, without introducing foreign genes. One example of "molecular scissors" is the CRISPR-Cas9 system. Explain the steps involved in genome editing with this system, and its benefits/limitations for plant breeders.**

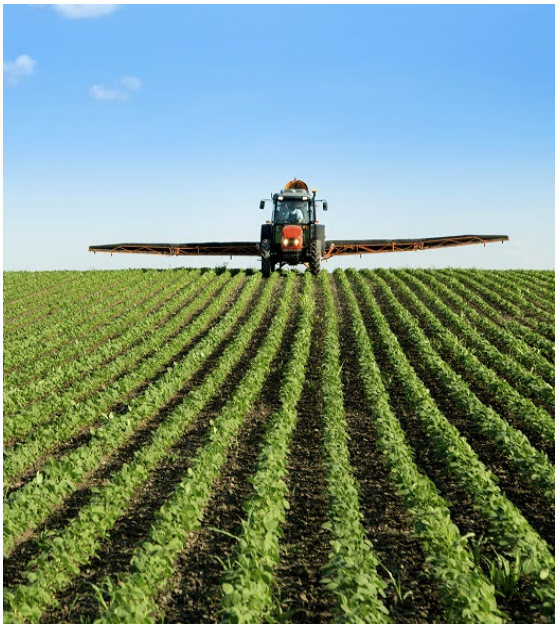
   Genome editing consists of using an enzyme system to change the DNA of a cell at a specified sequence. This is seen as an "improved" version of mutagenesis, which is not regulated as a GMO.

   There are different systems that can be used for genome editing, one of which is the CRISPR-Cas9 system, which precisely cuts and pastes a gene into a plant's genome. An RNA molecule attached to Cas9, a bacterial enzyme, is introduced into a cell. The RNA locates the specific segment of DNA that contains the gene a plant breeder wants to edit. When the RNA molecule finds the right gene, it attaches itself to that part of the DNA sequence. Cas9 cuts the DNA sequence at the desired site in the genome.

   Plant breeders can enable or disable a particular gene, or insert a new segment of synthetic DNA into the cut to alter a gene's function. The synthetic DNA is engineered in a laboratory, rather than taken from another organism, which means that the new organism is not transgenic—there is no introduction of foreign genetic material with this system.

   The advantage of using this technology is that plant breeders can directly alter a gene. They no longer have to rely on random mutations from mutagenesis, or the time-consuming selection and crossbreeding of plants to create new desirable traits. Its low cost may make it possible for university and government scientists to quickly develop useful crop traits. Some biologists, however, feel that genome editing is limited by the fact that you cannot alter a plant to do something it does not have the genetic capacity to accomplish—something that recombinant DNA technology, on the other hand, can do.

A CASE STUDY: HERBICIDE-TOLERANT CROPS AND SUSTAINABLE AGRICULTURE



While weeds have been detrimental to farming for thousands of years—they compete with crops for light, water, nutrients, and space—the ways in which farmers protect their crops from weeds has changed over the past century. This is due to changes in farming practices and new technologies, as well as environmental concerns.

Since the second half of the 1990s, it has been possible for farmers to grow herbicide-tolerant (HT) crops. These are genetically engineered to survive the application of specific herbicides that would once have destroyed the crop, along with the targeted weeds. Since the adoption of HT crops, there has been considerable debate regarding their environmental impact and their impact on the sustainability of Canadian farms.

Critical Thinking

In this activity, you will first define the term "sustainable agriculture". You will then analyze five written texts to determine if growing herbicide-tolerant crops can play a role in sustainable agriculture. Based on these texts, you will then write your own objective analysis of the subject.

Objective

By developing your own argument on whether or not herbicide-tolerant crops should play a role in sustainable agriculture, you will develop critical reading and thinking skills, as well as a better understanding of the impact of biotechnology on agriculture in Canada.

Ingenium
CANADA AGRICULTURE AND FOOD MUSEUM
MUSÉE DE L'AGRICULTURE ET DE L'ALIMENTATION DU CANADA
Canada

Analysis of Texts

To help develop your critical thinking and reading skills, you will first read two articles developed for students at the University of Toronto: "*Critical Reading Toward Critical Writing*" and "*Research Using the Internet.*" Using the recommendations in these two articles, you will first research the term "sustainable agriculture" and form a definition for your written analysis.

http://advice.writing.utoronto.ca/researching/critical
http://advice.writing.utoronto.ca/researching/research-using-internet/

You will then analyze the following text: "*New study: GMO crops reduce pesticide use, greenhouse gas emissions"* (2020) by Joan Conrow (Alliance for Science).

https://allianceforscience.cornell.edu/blog/2020/07/new-study-gmo-crops-reduce-pesticide-use-greenhouse-gas-emissions/

Using recommendations provided in the articles above, you must find and analyze four additional written texts pertaining to herbicide-tolerant crops and sustainable agriculture (using both Internet and library resources).

Based on your reading of these five texts, you will write your own critical analysis as to whether or not herbicide-tolerant crops should play a role in sustainable agriculture, citing sources in support of your argument.

A CASE STUDY: GENETICALLY ENGINEERED FOOD AID TO AFRICA

In 2002, six countries in southern Africa—Angola, Lesotho, Malawi, Mozambique, Swaziland, Zambia and Zimbabwe—were facing a severe food crisis. There were multiple underlying causes for the crisis, and they varied from country to country. Some of the principal causes were severe drought, heavy rain/floods, depletion of grain reserves, sharp rises in the prices of staple foods, and the impact of HIV/AIDS.

In response to the crisis, the U.S. offered food aid to these countries. This triggered international debates, however, since the food aid included genetically engineered corn. The affected countries raised various concerns about letting genetically engineered food aid cross their borders. Some rejected GM food aid, while others allowed it if it was milled.

Critical Thinking

In this activity, you will analyze five written texts pertaining to the concerns raised by countries in southern Africa regarding the possibility of genetically engineered food aid crossing their borders. You will then write your own objective analysis based on these texts.

Objective

By developing your own arguments about why some southern African countries were concerned about letting genetically engineered food aid cross their borders, you will develop critical reading and thinking skills, as well as a better understanding of the impact of genetically engineered crops in other parts of the world.

Ingenium
CANADA AGRICULTURE AND FOOD MUSEUM
MUSÉE DE L'AGRICULTURE ET DE L'ALIMENTATION DU CANADA
Canada

Analysis of Texts

To help develop your critical thinking and reading skills, you will first read two articles developed for students at the University of Toronto: "*Critical Reading Toward Critical Writing*" and "*Research Using the Internet.*"

http://advice.writing.utoronto.ca/researching/critical
http://advice.writing.utoronto.ca/researching/research-using-internet/

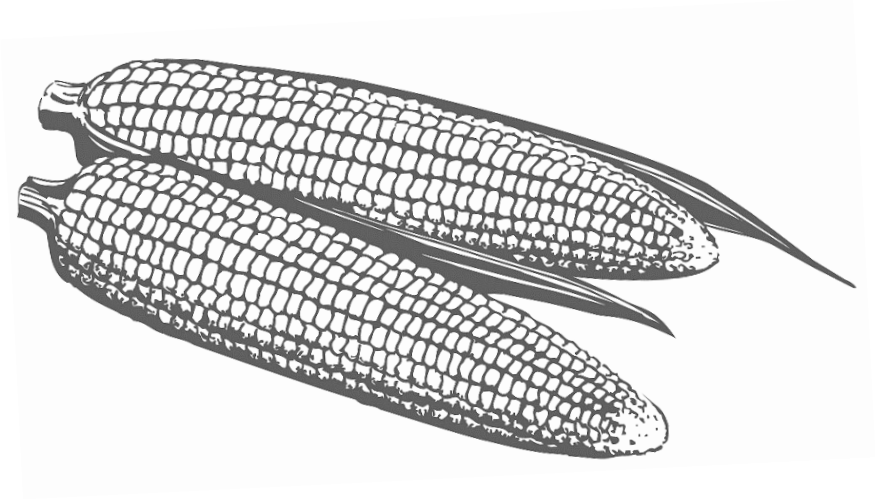
Using the recommendations provided in these two articles, you will analyze the following text: "*Feeding the Famine? American Food Aid and the GMO Debate in Southern Africa"* by Noah Zerbe (Food Policy 29 (2004) 593-608).

https://faculty.washington.edu/jhannah/geog270aut07/readings/GreenGeneRevolutions/Zerbe%20-%20GMOs%20in%20food%20aid.pdf

Using the recommendations given in the articles above, you must find and analyze four additional written texts pertaining to genetically engineered food aid to southern African countries (using both Internet and library resources).

Based on your reading of these five texts, you will write your own critical analysis of why some southern African countries were concerned about genetically engineered food aid crossing their borders, citing sources in support of your argument. You can also compare the reaction of these countries in 2002 to current food-aid policy in that same part of the world.

Note: The term "genetically modified food" (GM Food) is often used in lieu of "genetically engineered food". To use the proper definitions, *all* of today's agricultural crops are genetically modified organisms or foods, as they are the result of human intervention. The correct term for transgenic foods (foods containing DNA from foreign organisms) is "genetically engineered".



A CASE STUDY: DIFFERENT APPLICATIONS OF SALMON GENOMIC RESEARCH

For decades, scientists have been studying salmon: the common name for a variety of related fish species. By sequencing the salmon genome—its genetic information—scientists are better able to understand the factors involved in salmon's growth, health, reproduction and evolution. Interest in the conservation of declining wild salmon populations, as well as a growing demand for salmon as food, have fuelled research in sequencing the salmon genome.

Critical Thinking

In this activity, you will read about two projects involving the genetic improvement of salmon, and will research each project's possible environmental impact and its importance for food security. You will then decide which project to fund, supporting your decision in a report on your findings.

Please note: The term "environmental impact" refers to both negative and beneficial aspects.

Objective

By analyzing the environmental impact of two salmon projects, as well as their importance for food security, you will develop critical reading and thinking skills. You will also gain a better understanding of the current applications of salmon genomic research. In addition, you will identify a variety of careers related to science, along with important contributions made by Canadian scientists.

Scenario

You are a Canadian financier, and a member of an organization interested in salmon aquaculture and efforts to replenish and protect wild salmon. The organization is looking to invest a large sum of money into a salmon project. You are approached by two teams of scientists looking for funding of their projects.

One of these is Aqua Bounty Technologies Inc., an American company that has created the AquAdvantage® salmon, a genetically modified breed of salmon that grows faster than traditional farmed salmon. The other is a team from EPIC4 (Enhancing Production in Coho: Culture, Community, Catch), led by Dr. Willie Davidson and Dr. Louis Bernatchez, seeking to revive and sustain the wild Coho Salmon fisheries, in addition to developing British Colombia's land-based aquaculture industry.

You must research both salmon projects—in particular, their possible environmental impact and their potential role in achieving food security—in order to brief other members of your funding organization on the two options.

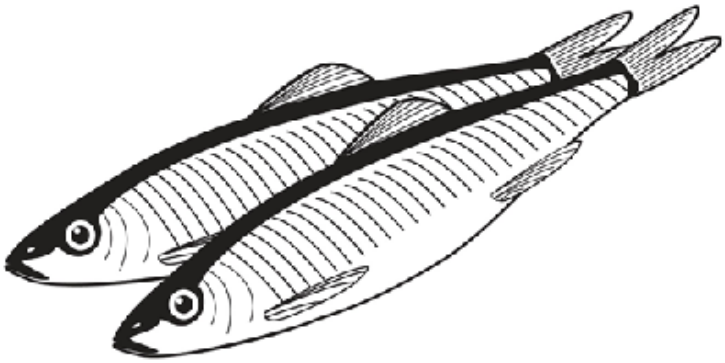
http://www.genomecanada.ca/en/enhancing-production-coho-culture-community-catch-epic4
http://www.sfu.ca/epic4/
https://fas.org/sgp/crs/misc/R43518.pdf

Research and Final Report

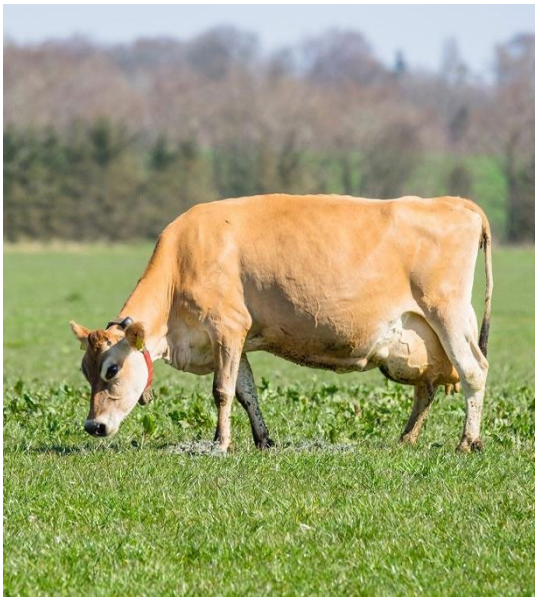
You must find and analyze information pertaining to both salmon projects (some resources are listed below). To help develop your critical thinking and reading skills, you will first read two articles developed for students at the University of Toronto: "*Critical Reading Toward Critical Writing*" and "*Research Using the Internet.*" Using the recommendations provided in these two articles, you will analyze the information you have found.

http://advice.writing.utoronto.ca/researching/critical
http://advice.writing.utoronto.ca/researching/research-using-internet/

Based on your reading of these resources, you will decide which one of these projects the organization should financially support, based on their possible environmental impact and their potential role in achieving food security. Provide a written report that cites the sources upon which you based your decision.



A CASE STUDY: THE DIGESTIVE SYSTEM OF THE DAIRY COW



A dairy cow is a ruminant, meaning that she ruminates or re-chews her food. Her stomach, divided into four compartments—the rumen, the reticulum, the omasum and the abomasum—allows her to digest plant fibre. The rumen is full of food-fermenting microorganisms. These microorganisms feed off plant fibre, which they break down and transform into nutrients that the rumen can absorb.

This process of converting cellulose-based fibre into energy also produces gases such as methane and carbon dioxide. The dilemma lies in the fact that, although we know these greenhouse gas emissions contribute to climate change, the dairy industry provides us with dairy and meat.

Understanding Concepts

In this activity, you will study the digestive system of the dairy cow—more specifically, the role played by the microorganisms that live in the rumen, as well as the gases they produce. You will also investigate how scientists are attempting to alleviate the environmental impact of these gases. You will write an information brief on your findings.

Objective

By analyzing the inner workings of the rumen, you will develop a better understanding of the digestive system of a ruminant. Investigating the possible solutions to greenhouse gas emissions currently being suggested by scientists will allow you to familiarize yourself with scientific advances in the field of agriculture.

Ingenium
CANADA AGRICULTURE AND FOOD MUSEUM
MUSÉE DE L'AGRICULTURE ET DE L'ALIMENTATION DU CANADA
Canada

Scenario

You are a research analyst for the Dairy Farmers of Canada, which is the national policy, lobbying and promotional organization representing the farmers who operate some 12,000 dairy farms across the country. A board member would like you to write an information brief for an upcoming public event, at which it is expected that the environmental impact of dairy farming will be brought into question. This board member would like you to explain how the microorganisms in the rumen convert cellulose-based fibre into energy, producing methane and carbon dioxide in the process. You must then describe how dairy farmers and scientific research projects are attempting to reduce the production of these greenhouse gases.

Research and Information Brief

You must find and analyze information pertaining to the digestive system of the dairy cow, as well as how the greenhouse gases resulting from the cow's digestive process can be reduced (some resources are listed below). To help develop your critical thinking and reading skills, you will first read two articles developed for students at the University of Toronto: *"Critical Reading Toward Critical Writing"* and *"Research Using the Internet."* Using the recommendations provided in these two articles, you will analyze the information you have found, and summarize your findings in an information brief, citing the sources you have used.

Resources

http://advice.writing.utoronto.ca/researching/critical
http://advice.writing.utoronto.ca/researching/research-using-internet/
https://extension.umn.edu/dairy-nutrition/ruminant-digestive-system
https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/4h8115/$FILE/DairyReference6.pdf
http://www.omafra.gov.on.ca/english/livestock/dairy/facts/greenhousegas.htm
https://agriculture.canada.ca/en/news-agriculture-and-agri-food-canada/scientific-achievements-agriculture/reducing-methane-emissions-livestock
https://agriculture.canada.ca/en/canadas-agriculture-sectors/fields-science/dr-karen-beauchemin
https://www.youtube.com/watch?v=rlqQgR2ttK8

DISTINGUISIHING MONOCOTS AND DICOTS

Courtesy of Peter Halasz / Wikimedia Commons

Angiosperms, commonly known as flowering plants, are divided into two distinct classes: monocots and dicots.

Monocots have only one seed leaf inside the seed coat. Usually thin, the seed leaf of a monocot does not contain the nutrients required to feed the plant's embryo.

Dicots have two seed leaves inside the seed coat. They are usually rounded and fat, because they contain the nutrients needed to feed the plant's embryo.

Monocots also differ from dicots in their leaves, stems, roots and flowers.

Monocots tend to have fibrous roots that extend in many directions. Dicot roots have one main root called a taproot, from which other, smaller roots, branch off. The vascular tissue (the circulatory system) of monocots is arranged in scattered bundles throughout the stem. In dicots, the vascular bundles are arranged in a ring. The leaves of monocots commonly have unbranched, parallel veins, whereas the leaves of dicots usually branch out from a main vein (reticulated). Finally, in monocots, flowers usually form in groups of three, while in dicots, flowers form in groups of four or five.

Please note: The following activity must be started at the beginning of the semester to allow it to be completed by the semester's end.

Growing Corn and Pea: Laboratory Activity Part I

In this laboratory activity, you'll observe the differences between monocot and dicot flowering plants by observing and comparing the growth of a corn plant to that of a pea plant.

Objective

This laboratory activity will help you identify the characteristics of monocot and dicot plants.

Ingenium

CANADA AGRICULTURE AND FOOD MUSEUM
MUSÉE DE L'AGRICULTURE ET DE L'ALIMENTATION DU CANADA

Canada

Materials

- Pea seeds
- Corn seeds (dwarf variety, if possible; shorter growing season)
- 8 growing containers (about 5 cm deep)
- 6 resalable snack-sized bags
- Potting mix
- 12 cotton balls
- Pipette
- Grow light
- Popsicle sticks
- Masking tape

Instructions

1. Fill the growing containers with potting mix. Plant four pea seeds and four corn seeds—one seed per container—following planting instructions on the seed packets.
2. Identify each container by writing the type of seed on a popsicle stick.
3. Gently stretch out each cotton ball and use the pipette to dampen the centre of each cotton ball with 2–3 drops of water.
4. Place either a pea or corn seed on each dampened area (for a total of six canola seeds and six corn seeds) and fold each cotton ball over its seed so that the seed is no longer visible.
5. Place two cotton balls—with the same type of seed—in each zip-lock bag (leave the bags open to allow air to circulate).
6. Identify each zip-lock bag by writing the type of seed on masking tape.
7. Place growing containers and zip-lock bags under the growing light.
8. Water the seedlings throughout the coming weeks.
9. As the plants germinate and begin to grow, observe and draw the main stages in the development of the two plants. *(The seedlings in the zip-lock bags will allow you to draw the first stage of growth of each plant.)* On your diagrams, identify and label the following: emerging roots, cotyledons, root hairs, first true leaves and flowers. Using the diagrams you have drawn, identify whether the corn and canola plants are monocots or dicots.

Name: _____ Date: _____

DISTINGUISIHING MONOCOTS AND DICOTS

Diagrams of stages in the growth of a pea plant.

Name: _____ Date: _____

DISTINGUISIHING MONOCOTS AND DICOTS

Diagrams of stages in the growth of a corn plant.

Name: _____ Date: _____

DISTINGUISIHING MONOCOTS AND DICOTS

Observe and record on the following chart any differences you discover between the plants.

	Pea	Corn
Seed		
Root		
Stem		
Leaf		
Flower		

Name: _____ Date: _____

Identifying Vascular Differences in Plants: Lab Activity Part II

In this laboratory activity, you will use a microscope to observe and compare the vascular tissues of a corn plant and a pea plant.

Objective

This laboratory activity will help you identify and compare the vascular tissues of monocots and dicots.

Materials

- Stem from a canola plant
- Stem from a corn plant
- Microscope slides
- Cover slips
- Scalpel or single-edged razor blade
- Compound light microscope
- Distilled water at room temperature
- Methylene blue solution
- Tweezers
- Petri dishes
- Paper towels
- Gloves
- Safety goggles
- Lab coat

Instructions

1. Put on safety goggles, a lab coat, and gloves.
2. Cut a 2.5-cm piece from the middle of the corn stalk and place it in a petri dish containing distilled water at room temperature. Repeat this process with the pea plant.
3. While holding the piece of corn stalk, cut a dozen thin cross-sections, using the scalpel or razor blade. Repeat the process for the piece of pea plant.

   Safety first! Be sure to cut away from yourself and others nearby.

4. Select the thinnest cross-section of each plant using tweezers and transfer each to an individual microscope slide.
5. Add a drop of distilled water to each specimen, and place a cover slip on top.
6. Add a drop of methylene blue solution to the side of each cover slip. Place a small piece of paper towel at the opposite edge of the cover slip. The absorbent paper will draw the dye to the opposite side, causing it to flow over and stain the cells of your specimen.
7. Examine the stained specimens with a compound light microscope.
8. Draw and label your findings on the page below.

Draw a diagram of the vascular tissue in the stem of a corn plant:

Draw a diagram of the vascular tissue in the stem of a pea plant: