Agri-science Resources for High School Sciences

Biotechnology 

Biology

Science

Grade 10-12

Biology Classroom

Individual reading

DESCRIPTION

Biotechnology is a relatively new science with direct applications to the Agriculture industry. This article describes some of the pros and cons of Biotechnology. A few modern breakthroughs are described which apply to Prince Edward Island. These include genetically altered potatoes and tomatoes. Bovine Somatotropin and Pharming in animals are also described.

LEARNING OUTCOMES

Students will:
- learn about new advances in biotechnology
- see how this technology applies to the agriculture industry on Prince Edward Island

READINESS ACTIVITIES

Students should:
- discover the attitudes of friends, parents, or relatives towards biotechnology
- examine their own opinions and see if they change after reading the article

MATERIALS

- copy of article

Biotechnology

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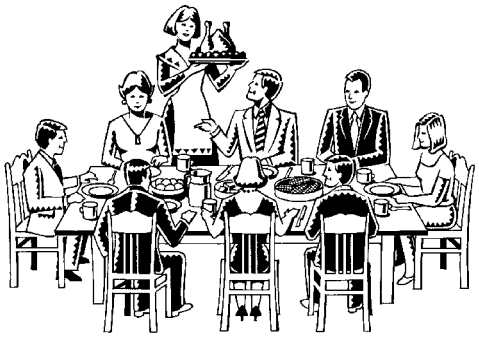
Biology

Introduction

One of the newest, yet controversial fields in science today is **biotechnology**. Biotechnology began in the 1970s after the development of **genetic engineering** that allowed scientists to modify the genetic material of living cells. Genetic engineering is the manipulation of DNA molecules to produce modified plants, animals, or other organisms. DNA is the part of a cell that controls the genetic information of an animal or plant. DNA is a double-stranded molecule that is present in every cell of an organism. The genetic information is contained in individual units or sections of DNA called **genes**. The genes that are passed from parent to offspring determine the traits that the offspring will have. Scientists are now able to isolate the gene or genes for the traits they want in one animal or plant and move them into another. The movement of a gene from one organism to another is called **recombinant DNA technology**. This technology is advancing at a very rapid pace.

Why?

There are people who question why the world needs biotechnology. Countries like Canada have a surplus of quality food. There are many countries in the world that do not have enough food to go around. One major challenge of the future will be meeting the growing demand for food as the planet's population expands. Farmers have been improving their crops for many years by developing new practices. Now the search is on for ways to speed up the process and create new crops which display distinctive advantages over current strains. The goal of scientists is to improve crop yields and to diminish further damage to the environment through the over-use of chemicals. Scientists have turned to biotechnology to develop these new crops. Many of these plants are able to protect themselves from the viruses and insects which damage them.



Causes for Concern

Not everyone views genetically engineered foods as a welcome development. Several organizations have expressed concerns in many areas. This is a list of some of these concerns, followed by the counter argument:

✗ - some people are concerned that genetically altering foods could change their nutritional value by lowering vitamin content or other nutrients.

✔ - others point out that several genetic engineering projects are designed to increase, not lower the health attributes of foods.

✗ - There is some concern that the process of inserting genes is not precise. Scientists can not tell exactly where they go or how many reach their target.

✔ - supporters of genetic engineering insist that it is more precise than traditional **crossbreeding** methods and carries less risk of undesired traits being transferred.

✗ - Some fear that a foreign gene may not behave in a new crop the way it did in the original species. It may interact with genes around it or with its new environment to produce undesirable traits.

✔ - Others point out that traditional plant breeders use well-established practices to eliminate plants with adverse traits prior to commercial use and that transgenic plant breeders can do the same.

✗ - Concerns have been raised about the effect of genetically engineered foods on special populations, such as infants or people suffering from other conditions or diseases. Testing is done on healthy adults, so effects that might emerge in other populations could be missed.

✔ - This situation is not unique to genetically engineered foods. It would be very difficult to test any new product on every specialized population before it is marketed.

✗ - A reaction might occur between two food compounds that may be harmless separately, but together could be **toxic**. There are also concerns that harmless plants that have toxic relatives may have the toxic gene turned on in a recombinant plant.

✔ - Genetic changes that can lead to unexpected toxins can occur not only in genetically transformed plants, but also in plants developed through traditional breeding practices or as a natural part of growth.

✗ - Some people fear that the genes for **resistance** which are inserted into plants will somehow be passed to weeds. Insects may build up resistance to the new **pesticide**. Some think that a gene that is intended to be toxic only for insects will somehow **mutate** and become toxic to humans as well.

✔ - Others cite the fact that the potential of pests to develop resistance against defence mechanisms of crops is well-known and is not unique to genetically engineered plants. Insects may develop resistance to a crop defence no matter how it was developed.

✗ - There are individuals who see a conflict of interest where a company's own scientific data is used to determine food safety. They would like to see a great deal more independent testing.

✔ - Some companies resent this implication that test results from their own laboratories are false. They argue that it is to their benefit to produce safe, beneficial food products because there is no profit in bad products.

✗ - Others fear that new plant species may upset the balance of nature, changing the delicate relationships between crop plants, weeds, and the animals that consume them.

✔ - Supporters of biotechnology foresee a different day when not one, but many improved crop varieties could flourish in areas of the world that currently can not produce enough food crops for the entire population.

Of course there are many more points for both sides of the issue. Debate about genetically engineered foods is a good thing. It helps assure that the companies developing genetically engineered products will continue to address consumer concerns. This way the products will undergo rigorous research, and thus increase food safety. This article will describe some new biotechnology that relates to Prince Edward Island. Remember that there are two sides to each issue. Hopefully, this will read as unbiased as possible and enable students to develop their own opinions.

Plant Products

There are numerous engineered crops being developed and made available for public consumption. Farmers have their choice of several **herbicide**, insect, and disease resistant **hybrids** and varieties. Herbicide tolerance and insect resistance are the major genetic constructions in field crops, while delayed ripening and flavour enhancement are the novel properties in vegetables such as tomatoes. Most of this technology began with major field crops such as corn, soybeans, cotton, and potatoes. Now work is being done on specialty crops such as fruits, vegetables, and forages. The amount of acreage occupied by these plants is expected to increase rapidly over the next few years.

Potatoes

The potato is the most popular vegetable among North American consumers. On Prince Edward Island, the mineral rich red soil, warm days, cool nights, and plentiful rainfall provides ideal conditions for growing potatoes. In 1996, 1,179,400 tonnes of potatoes were produced on Prince Edward Island. This accounts for about 30 % of all the potatoes grown in Canada; fairly impressive for such a small province. However, potatoes are not especially easy to grow. Each year, a significant amount of crops are lost to disease and **pests**.

Bt Protein

Plants are now being engineered to produce Bacillus thuringiensis (Bt). This is a bacterium which occurs naturally in the soil. There are **strains** of Bt that produce proteins that kill certain insects. When these insects ingest the protein, the function of their digestive system is disrupted, producing slow growth and eventually death. Another positive feature of Bt is that it is not harmful to humans, other mammals, birds, fish, or beneficial insects. It is not a very effective pesticide for several reasons. It is relatively expensive, it must be eaten by insects as opposed to simple exposure, it is broken down by sunlight, and rain washes it away from plants. This is why Bt is most effective when it is actually contained in the plant itself.

Colorado potato beetle

The Colorado potato beetle is very harmful to the potato industry. The beetle feeds on the growing plant leaves and stems during the growing season, stunting the plant and cutting yields. Many applications of chemical sprays are usually needed to control the pest. Bt is especially effective against the Colorado potato beetle. When the Bt gene is inserted into the potato plant, the plant produces a protein that is toxic to the beetle. Therefore, when the beetle feeds on the genetically improved plant, the toxic protein interferes with its digestive system and it dies.

NatureMark potatoes

Because the potato is so important to the Island, any new developments in technology will have an impact here. A maritime food chain introduced the NewLeaf potato to grocery stores in the spring of 1997. On April 2, 1997, The Guardian ran a front page story on the new development. The NewLeaf product is marketed by NatureMark potatoes, a division of the multinational Monsanto company. It has taken many years for this product to reach the produce aisle. Health Canada has concluded that the NewLeaf potato is as safe and nutritious as other commercially-available varieties.

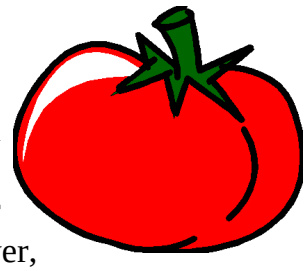
This variety has built-in resistance to the Colorado potato beetle in the form of Bt. Only one farmer from Prince Edward Island had grown the NewLeaf variety before the spring of 1997. Denton Ellis from O'Leary grew 100 acres of the potato on his farm.

The Future

There are more genetically-altered potatoes on the way. Several virus-resistant potato varieties are planned for release in 1998. These include potatoes stacked with both Bt and resistance to potato leafroll virus and potato virus Y. This PVY virus is well-known by Islanders because of its tremendous effect on the potato industry a few years ago.

Genetic engineering is also being used to develop potatoes with more starch and less water to prevent damage during harvesting. A potato with less water content may absorb less oil when it is fried, producing healthier french fries or potato chips. Other researchers are using genes from chicken embryos and insect immune systems to try to make potatoes more disease resistant.

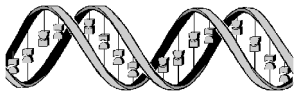
Tomatoes



Although the tomato industry is not as important to Prince Edward Island, there are many home gardeners who grow them. Many people eat tomatoes in salads and sandwiches. There are also many other tomato products such as ketchup, spaghetti sauce, and soups. However, tomatoes found in local supermarkets are not very tasty compared to garden-grown, vine-ripened tomatoes. Consumers in Northern regions must rely on tomatoes shipped from the south to get fresh tomatoes at most times of the year.

Taste Problem

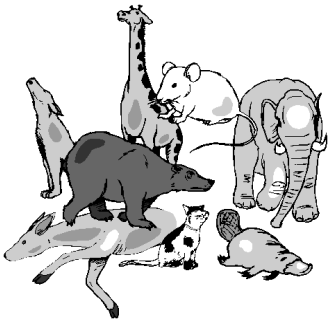
In order for tomatoes to be shipped, they must be picked at the mature-green stage. Mature-green tomatoes have already absorbed all the vitamins and nutrients from the plant that they can, but have not started to produce the natural **ethylene** gas that triggers ripening. The green tomatoes are then put into ripening rooms, where ethylene gas is released. They spend 3 to 4 days in the ripening room before being shipped at temperatures not lower than 10 ^{o}C. Cooler temperatures destroy tomato flavour. When tomatoes arrive at the grocery store, they are still 3 to 4 days away from being ripe. Calgene, a company in California, has genetically engineered the tomato to help overcome this problem. The name of the vegetable they developed is the Flavr Savr Tomato.



Flavr Savr

The scientists have developed a tomato with a gene that slows the natural softening process that accompanies ripening. **Pectin** occurs in many fruits and contributes to their firmness. The pectin in ripening tomatoes is degraded by an enzyme called polygalacturonase. As the pectin is destroyed, the cell walls of tomatoes break down and then soften. The scientists were able to reduce the amount of this enzyme in tomatoes, which slowed the rate of cell wall breakdown and produced a firmer fruit for a longer time. Therefore, the Flavr Savr tomato spends more days on the vine than other tomatoes. This allows sugars to be transported to the fruit, resulting in more flavour. At the same time, the tomato remains firm enough to be shipped. Because of the genetic modifications, the Flavr Savr also has a longer shelf life than regular supermarket tomatoes.

Animal Products



Biotechnology can also be applied to animals. This is where animal rights' groups become involved in the debate. They believe that animals should not be modified genetically. These are two examples of biotechnology involving animals.

Milk Industry

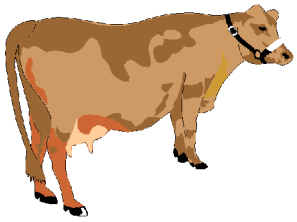
The milk industry is also very important to Prince Edward Island. Many dairy farms on the Island have been owned by the same family for several generations. On a national level, Quebec and Ontario account for most of the milk production in the country. Still, according to Statistics Canada, in 1995 the cows in this small province were able to produce about 95,400,000 litres of milk and cream. New technology and advancing farming practices continues to increase production. None of these past discoveries have had such a dramatic impact as Bovine somatotropin.

Bovine Somatotropin

Bovine Somatotropin (bST) is a metabolic protein **hormone** used to increase milk production in dairy cows. Hormones are chemicals that are secreted by glands within the body. **Somatotropins** (growth hormones) are protein hormones made in the **pituitary gland** located at the base of the animals brain. These substances play a key role as the master hormone that regulates both growth in mammals and the metabolism of nutrients in the diet. Milk production in cows is under hormonal control. In order for cows to continue producing milk, these growth hormones must be continuously secreted. In the 1930s, it was discovered that injecting bST into milk-producing cows can significantly increase milk production.

Source of the Hormone

Until recently, the only source of bST was from the pituitary glands of slaughtered cattle. Only small quantities of bST were available, and it was very expensive. Using biotechnology, scientists were able to produce a great deal of the hormone at a much lower cost. First they determined which gene in cattle controls the production of bST. They removed the gene from cattle and inserted it into a bacterium called Escherichia coli. This bacterium acts like a tiny factory and produces large amounts of rbST (recombinant bovine somatotropin) in controlled laboratory conditions. The rbST produced by the bacteria is purified and then injected into cattle.



Mode of Action

To affect a cows milk production, rbST must be injected into the animal on a regular basis. Feeding rbST to cows will not work because the hormone is broken down in the digestive system of the cow. Although most of details have been explained, scientists are still not exactly sure how rbST increases milk production. This is why there are some concerns. It is thought that the hormone increases blood flow to the gland responsible for producing milk (mammary gland). This increases the amount of nutrients available for milk production. Researchers have found a milk production increase of 8.4 pounds per day. To meet the needs for this increased milk production, treated cows consume from 10 to 20 percent more food in the form of grain and **forage**. There are many factors which affect the response of cows to rbST. These include quality of management, milking practices, nutrition, cow condition, and environmental conditions.

World Debate

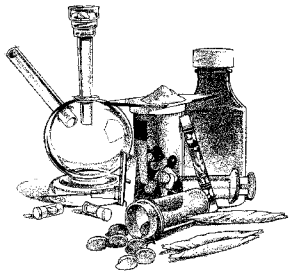
The commercial use of rbST in dairy cattle is controversial and has stirred heated debate among the dairy industry, activist groups, and consumers. The status of the hormone drug is different in many countries. The company Monsanto was licensed to sell Posilac, the trade name for bST, by the US Food and Drug Administration in November, 1993. BST is also allowed in Mexico. The European Union has already imposed a moratorium on the drug until the year 2000. This means release of the drug is delayed until more research and testing can be done.

Canada

In Canada, for a new veterinary drug to be approved, it must be investigated by Health Canada. A demonstration must be made that there is no risk to humans who consume animal products from treated animals, that animal health is not adversely affected, and that the drug is effective. If these questions are answered satisfactorily, Health Canada approves the drug. The Ministers of Agriculture and Health then formally approve the products for sale or use. This whole process can take up to several years. However, the process has enabled Canada to become recognized around the world as a leader in the standards of health of its human and animal populations.

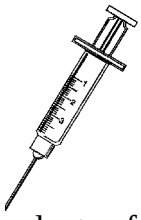
With respect to bST, the approval process was much more complex. On August 17, 1994, in response to the recommendation that a moratorium be put in place, the government obtained a commitment from the manufacturers of rbST for a one-year voluntary delay on the use and sale of rbST in Canada. In May of 1995, the rBST Task Force presented a "Review of the Potential Impact of Recombinant Bovine Somatotropin in Canada" to the Minister of Agriculture and Agri-Food Canada. Health Canada is still in the process of investigating rbST hormone. As of July 14, 1997, The Dairy Farmers of Canada, a national organization that represents all dairy farmers in Canada, passed a resolution asking the federal government to fulfill three specific conditions before finalizing its authorization for the licensing of rbST in Canada. The dairy farmers requested that the Auditor General of Canada complete a comprehensive audit of the approval process of rbST to ensure that any claims questioning its integrity are fully dispelled and that the safety of the product be confirmed by recognized international health organizations such as the FAO/WHO Codex Alimentarius Commission. Finally, Health Canada must agree to fully inform the public about the assessment process and the rationale it used in its evaluation of rbST. What the future holds for this product is still unclear. It is certain that it will take more time before rbST-derived milk products appear in grocery stores across Canada.

Pharming



Another application of biotechnology involving animals is Pharming. Pharming is the production of human pharmaceutical drugs in farm animals. There are many drugs that are needed by humans which are made of protein. **Insulin** is a good example. This protein is used to treat diabetes. Previously, the only way of obtaining insulin was to collect it from slaughtered pigs. Therefore, protein drugs such as insulin, were available in extremely limited supplies.

Human Drugs



Using genetic engineering, the DNA gene for a protein drug of interest can be transferred into another organism that will produce large amounts of the drug. Human genes can be transferred to microorganisms or other animals to make human proteins. The first successful products of this technology were protein drugs like insulin and growth hormone. These drugs do not have to be produced by mammals to be active in mammals. Genetically engineered bacteria can be used to manufacture these drugs. Bacteria have already been used in the production of insulin.

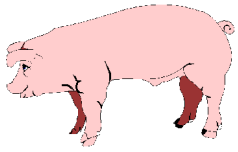
Pharm Animals

Unfortunately, microorganisms such as bacteria are not able to produce all human proteins. Some protein drugs require modifications that only cells of higher organisms like mammals can provide. This is why pharm animals are used. These animals are used as simple factories that can produce any human protein. A transgenic animal for pharmaceutical production should produce the desired drug at high levels without endangering its own health. The animal should also pass its ability to produce the drug at high levels to its offspring.

Why the Milk?

Livestock animals are the best subjects for this technology. The current strategy is to insert the DNA gene for the protein drug into the animal so that the drug is made only in the milk. Since the **mammary gland** and milk are not involved in the main life support systems of the animal, there is virtually no danger of disease or harm to the animal in making the foreign protein drug. The drug can then be purified from the milk which can easily be obtained from the animal.

Blood Donors



Although most protein drugs are made in milk, one exception is human **hemoglobin** that is being made in pig blood. The human hemoglobin is then extracted and used as a blood substitute for human blood transfusions. This method will be one of the few exceptions to the whole process. This is because to recover the human hemoglobin, the animal producing it must be slaughtered. That is a costly procedure considering how difficult it is to obtain a successful transgenic animal and the long time periods involved for the animals to mature. Obtaining the drugs from milk is a much better solution because the animal is never harmed. Still, this does offer an emergency supply of blood which may not be available from blood donors.

Future of Pharming

Transgenic animals will likely be raised by the pharmaceutical companies. The technology is still in the development stage and may be available to the public by the year 2000. Human drugs purified from animal milk or blood are likely to required exceptional levels of safety testing before animal and human health concerns are addressed to the satisfaction of consumers. In the future, animals may be used to produce human organs.

Activities

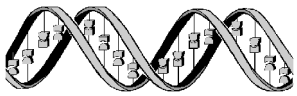
Organize a debate in the classroom about one or all of these issues. What you have just read only touches on all the new discoveries being made in biotechnology. The subject has been in the news quite often. Use magazines, old newspapers, books, or whatever to find your information. Any students in your class that live on a farm would also be a good resource. Every issue has a good argument for each side. This should make for a very good debate. It should also give students an idea of the kinds of arguments which are in the process of being formed over this issue.

The class could also arrange a forum or panel presentation on the subject of Biotechnology. Arrange for several volunteers from the agriculture industry to participate in this activity. It should be possible to get several individuals on both the pro and con sides of the issue.

Glossary of Terms

biotechnology	use of cells or components of cells to produce products or processes
crossbreeding	with animals, the breeding of one recognized breed of animals to another recognized breed.
ethylene	gas used in the process of ripening tomatoes
forage	crop plants grown for their vegetative growth and fed to animals
gene	a unit of hereditary material located on a chromosome
genetic engineering	movement of genes from one cell to another
hemoglobin	the pigment found in red blood cells
herbicide	a substance used to kill weeds
hormones	chemicals released by cells that affect cells in other parts of the body. Only a small amount of hormone is required to alter cell metabolism.
hybrids	plant or animal offspring from crossing two different species or varieties

Biotechnology



insulin	chemical used to control blood sugar levels. In most people, insulin is secreted when blood sugar levels are high
mammary gland	gland of the milk-producing system in the female
mutate	when the DNA within a chromosome is altered. Most mutations change the appearance of the organism
pectin	material which gives structure and firmness to fruits and vegetables
pesticide	chemical used to control pests
pests	any organism that adversely affects man's activities
pituitary gland	gland which secretes chemical hormones in the body
recombinant DNA technology	an application of genetic engineering in which genetic information from one organism is spliced into the chromosome of another organism
resistance	power to ward off disease
somatotropins	growth hormones secreted from the pituitary gland
strains	a certain stock or specific breed of an organism
toxic	a poisonous substance, causing injury to animals or plants

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