

# Genetically Modified Crops: Greed or Need?

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## **Introduction**

Genetic engineering of plants is the latest in a seamless continuum in the attempt to feed ourselves. Our burgeoning world population depends on the availability of sustainable seed stock that will flourish under harsh growing conditions with less reliance on chemical fertilizers and pesticides.

Genetic modifications are known by many different names including gene splicing, transgenics, DNA manipulation, recombinant DNA, and genetic engineering. These terms refer to the process of isolating genes of a known function from one organism, and then transferring a copy of that gene to a new host to introduce a desirable trait. In particular, genetically modified (GM) crops have been engineered to contain traits from unrelated organisms that enable plants to be resistant to pests, cold temperatures, drought, and disease. Most GM crops are grown in North America, but large areas of cultivation are found in Argentina, Australia, China, France, Mexico, and South Africa. There are currently more than 92 GM crop varieties being grown including new varieties of cotton, corn, rice, soybean, and potatoes.

There is a huge, emotional debate regarding GM crops and their patents. Supporters of GM crops argue that the world desperately needs GM crops to ensure food security and sustainability. This is especially true in developing countries that are experiencing famine due to drought conditions. The nutritional value of certain crops has also been improved and, as a result, certain malnutrition-related diseases are in decline. Genes for pest resistance have also been introduced into crop plants, eliminating the need for chemical applications and reducing the cost of production.

Opponents of GM crops are not convinced. There are many unknown risks and variables that can't be predicted. Pests and disease may adapt to the genetic modifications and undo the benefits of a genetically modified plant. Other concerns include food allergies, unintended cross pollination of organic crops, and loss of biodiversity.

Social concerns about corporate monopolies of highly successful, genetically altered seed stock companies are also closely monitored. Agrochemical companies (also known as life industries or life sciences) are controlling an increasing proportion of the whole

agricultural supply and distribution of crop seed. Smaller farms have to make tough economic choices that will impact their production and challenge their traditional farming and business practices.

### **Curriculum Focus**

This curriculum unit is aimed at presenting a balanced review of the social and environmental concerns of GM crops. Much information has been excluded due to limitations in length. A review of botanical science or plant genetics is not necessary but may allow teachers (and students) to better understand the bigger picture of GM crops.

Within the next few years, thousands of genetically modified food products could be put on the world market. There are many practical and ethical implications associated with GM crops that are not readily understood by the public. It is important for people to know the possible benefits and risks of this powerful new technology. Students will be asked to consider the following questions:

1. Are GM crops safe for the environment? Will they disrupt natural ecological processes, and displace wild species or natural populations?
2. Are genetically modified crops safe for human food and animal feed? How can we be sure a GM food will not be toxic to humans?
3. What are the moral, social and economic implications of patenting, and then controlling the distribution of successful GM crop seed?

### **Academic Setting**

This unit in genetically modified crops is targeted towards high school students who are academically gifted and prepared for challenging and relevant curriculum. This unit will be taught in a class that covers contemporary issues in science and health, but could be modified to fit the academic needs of many types of learners within various content classes.

Albuquerque High School is comprised of 2020 students. Sixty eight percent of these students are Hispanic, 20% are Anglo, 5% are African American, 5% are Native American, and the remaining are a mixture of Asian, African, and Russian. The "minority" ethnicity rates are higher at Albuquerque High School as compared to the other ten high schools in Albuquerque. The majority of the Hispanic students at Albuquerque High School are bilingual (Spanish) and have a strong identification with the Mexican culture. Many of these students are the children of immigrant Mexicans, or are recent immigrants

themselves.

Twenty five percent of the students attending Albuquerque High School receive free or reduced lunches. The percentage of students who receive free or reduced lunches is considered an indicator of socio-economic status. The higher the percentage, the more likely a school is to have a larger percentage of students with special needs related to poverty.

## **History of Genetically Modified Crops**

### **Low-Tech Plant Genetics**

There is evidence of land cultivation dating back to 11,000 BC in the region of the Near East known as the Fertile Crescent. These first crops were derivatives of wild grasses that were domesticated into wheat, barley and corn. According to researchers, prehistoric people realized that the seeds of certain plants were larger or had thinner coats than others, making them easier to process and germinate. By selecting these more desirable seeds for next year's crops, they unknowingly performed the first experiments in plant genetics.

### **Botany**

The study of plants as a discipline of science may be traced back to Aristotle (384-322 BC) who cultivated many species from diverse regions. Aristotle's disciple Theophrastus (371- 287 BC) carried on the work and wrote about it in his "Enquiry into Plants," in which he describes more than 500 different species. The ancient naturalist Dioscorides studied plants for their medical importance, and for a long period of time botanical studies were considered the domain of physicians, whose main interest was for remedies of various ills.

After this, centuries followed in which little attention was given to plants; botanical information was drawn from the works of ancient writers. Botany experienced a revival around the sixteenth century during which time several comprehensive books were published by leading herbalists. Botanical gardens and "glasshouses" were also becoming fashionable around this time and were cultivated for enjoyment as well as profit. As new territories were explored and exploited, plants and seed quickly traveled the globe introducing economic opportunities and the creation of social conditions (e.g., slavery) that made these expeditions profitable.

### *Grafting and Budding*

Fruit trees such as apple, orange, and grapefruit are the result of grafting, a simple method in plant genetics. Grafting provides desired

plant traits, such as sweetness, seed-less-ness, hardy roots, and resistance to pests and disease. Grafting is the process of inserting a cutting, or limb, of a desired plant (scion) into a rooted plant or tree (stock) in such a manner that the two cell layers unite and the inserted piece continues to grow. After the scion has developed the remaining stock is cut back, allowing the scion to bear fruit. Grafting hastens the time of fruiting by allowing the grafted plant to bear fruit earlier than if started from seed.

In the process of "budding," a small bit of bark bearing a bud is removed from the selected plant or tree. In the stem of the stock, a T-shaped cut is made in the bark and the flaps so formed are loosened. The prepared bud is inserted under the flaps, which are then pressed down over it and bound tightly into place to insure contact between the plant cell layers.

### *Hybrid Plants*

Hardiness, productivity and beauty can be enhanced through plant hybridization. A hybrid plant has parents of different species or of different strains within the same species. A hybrid plant combines desired traits from each parent, generally resulting in a superior, but often sterile, offspring. Hybrids are often infertile and even if they can reproduce, the resulting seed are not vigorous. Plants produced in this fashion are also known as cultivars.

### Gregor Mendel

The first steps in genetics were taken by botanists of the 18<sup>th</sup> and 19<sup>th</sup> centuries, mainly in Europe. Gregor Johann Mendel, a Jesuit monk in what is present-day Czechoslovakia, published the results of his meticulous study of heredity using garden peas. What was different about these results as compared to his predecessors' was a simple mathematical analysis of the flow of genes between generations. As a result of the importance of his work in heredity, the term Mendelian is applied to fundamental genetics.

### Green Revolution

In the 1960's and 1970's, a movement known as the Green Revolution introduced new farming methods and hybridized seeds for developing countries with food shortages. Plants were selected for disease resistance, increased yield, and adaptability to marginal land. Improved varieties and quantities of wheat, corn and rice were the results of careful monitoring of results and the subsequent sharing of information.

### High Tech Plant Genetics

There is still a need to physically clone and manipulate DNA, and then transfer it from plant to plant. New biotechnological tools have made the process easier with less chance for contamination or error. These tools have evolved over the last 30 years, but the "cut and paste" process of transplanting genes still continues in biotechnology companies.

### James Watson and Francis Crick

In 1953, James Watson, an American geneticist and biophysicist, and Francis Crick, a British biophysicist at the Cavendish Laboratories in Cambridge, England, developed a model for the structure of DNA. According to the Watson-Crick model, a DNA molecule consists of two spiral strands that wind around each other in a helical "twisted ladder" structure. Watson and Crick showed that each strand of the DNA molecule was a template for the other. During cell division the two strands separate, and on each strand a new "other half" is built, just like the one before. This way DNA can reproduce itself without changing its structure – except for occasional errors, or mutations (PBS Online, 1998).

The rungs of the twisted ladder are made up of complementary nucleotide "base pairs" known as thymine and adenine along with guanine and cytosine (T&A and G&C). Thymine will always bond with adenine, and guanine will always bond with cytosine. These letters are like a mini-alphabet which spell out messages for a cell. Different combinations of these letters (genes) spell out codes, and these codes tell the cell which specific proteins it should make and how to make them. Specifically, genes code for proteins and proteins are the building blocks of life. The DNA molecule is responsible for passing heredity information by instructing the cell to make certain proteins that will influence the growth, development, and appearance of the organism it is part of (Tagliaferro, 1999).

### Recombining Genes

Recombinant DNA (rDNA) technology – the ability to splice two sets of genes together and have the results expressed – was developed in 1973 by researchers in California. Several years later, scientists discovered how to cut DNA at exact points by manipulating enzymes. In effect, the enzymes are like molecular scissors that allow for DNA to be excised with precision. Around this same time researchers began crossing species lines, moving genes from animals into plants, from bacteria into plants. The hunt was on for new medicines, vaccines, pesticides and other specific traits to enhance plant performance and, ultimately, the human condition.

## Bioinformatics and Gene Banks

Massive amounts of information are generated by a single organism's genetic code (genome). The management of this data has developed an entire new discipline known as "Bioinformatics." A genome is divided into consecutively smaller and more manageable pieces that become part of a vast biological database. Gene banks store plant genes in the form of seeds but also as whole plants, pollen and cell cultures. Gene banks provide a broad range of plant genes from which breeders can develop new plant varieties with specific traits (Gene Bank).

## Methods of Gene Transfer in Plants

There are four primary methods of introducing an isolated gene into a host. These include:

1. Injection. This method is used primarily in animals. The new DNA is injected with a very small, sharp needle into the nucleus of a single cell. This cell is usually a fertilized egg that is replaced back in the female uterus where the injected cell is allowed to develop normally. Unfortunately, there is a high rate of failure when using this technique as cells infrequently take up and express the desired traits of the introduced DNA.
2. Biolistics. Biolistics is used in the genetic modification of plants and involves shooting new genes into the potential host. Microscopic particles of gold or titanium are coated in the DNA sections, which are to be introduced into the host. These are loaded into cartridges, similar to miniscule shotgun cartridges, which are then fired at the plant cell or seed. The process relies on some of the microscopic particles entering these cell nuclei and their DNA coating combining with the plant chromosomes.
3. Vectors. This method has the potential to be used in both plants and animals. It involves a bacteria or virus "ferrying" a new gene into a cell. Scientists replace a section of the bacteria's own DNA with a desired gene, and then introduce it to the organism, usually via the root system. This modification also occurs in nature.
4. Protoplast transformation. This method is also commonly used in plants. The cellulose in the plant wall is dissolved away using enzymes, leaving a protoplast. DNA can then be added to the protoplast, which are then cultured on a growth media. This encourages the protoplast to regrow cell walls and eventually grow into a transgenic plant (McHughen).

## Pressures on Present Day Agricultural Systems

Of all the land mass available on Earth for our burgeoning population, only 12% is viable for agricultural purposes (Kendall). Much of this land has been compromised by a combination of practices. These practices include:

1. Salinization of soils. Irrigation practices leach salts in the form of calcium carbonate and sodium chloride from irrigation water. After a period of time, a thin crust of salt begins to form on the soil, poisoning plants. Rising sea levels have also contaminated fresh water supplies along coastal farming areas. Salinization is a serious problem in Australia, Egypt, India, Mexico, Pakistan and the United States (Kendall).
2. Decrease in water supply. Currently, more than 40% of the world's nations are competing for water. Much irrigation depends on "fossil" underground water supplies, which are being pumped more rapidly than they are recharged (Postel). This problem affects portions of Africa, China, India, the United States, and several countries in the Middle East, especially Israel and Jordan.
3. Compaction of soils. Soils become compacted by the overuse of heavy farm equipment or over-tilling of fields. Plant roots are unable to penetrate the surrounding soil for nutrients and moisture. The weakened plant is then susceptible to disease and may not produce in quality or quantity, resulting in lowered crop yields
- 4) Overuse of fertilizers and pesticides. Annually in the USA, nearly ten billion pounds of fungicide, herbicide, insecticide, pesticide and fertilizers are spread or sprayed on farmers' fields. The figures are higher for Western Europe (Easterbrook). As a result, certain pests and diseases have become tolerant and require stronger doses of toxins to kill them. Farmers are reliant on chemical fertilizers for producing vigorous crop plants and increased yields. The cost of farm chemicals is high, both economically and environmentally.

#### Potential Benefits of GM Crops

##### *More Food for More People*

The supporters of biotechnology claim it will transform agriculture, giving us the ability to design crop plants to produce increased yields even in difficult situations, with far less reliance on chemicals. This will result in more food security for the world in the 21<sup>st</sup> century. Food security is the state in which all people at all times have access to enough safe and nutritious food to maintain a healthy and active life.

The world population is close to six billion and is growing at about 1.5 percent a year. At present, 87 million people are added to the world's population each year, with the greatest increases occurring in the most impoverished nations (Kendall). Although human fertility has been declining worldwide, it is not known when it will decline to replacement levels.

Population growth is of especial concern in India and China as their people account for nearly half of the developing world's population. Both countries have expanding populations and diminishing arable land and water resources (Kendall). According to the United Nations Food and Agricultural Organization (FAO) one in seven of the world's population are still chronically malnourished, including one in three children.

Analysts agree that the world needs to produce larger quantities of food. In the process of growing more crops, it is crucial that no further ecosystems are damaged. Global food demand is expected to increase as much as 50 percent in the next 15 to 25 years as a result of population growth and rising incomes (Panos).

#### *Prolonged Shelf Life of Fruits and Vegetables*

Farmers in all nations could benefit from crops with delayed ripening or softening characteristics, as this may allow them more flexibility in storing and selling their crops. Frequently, small-scale farms suffer heavy losses due to fruits and vegetables spoiling before they can be marketed.

#### *Improved Nutritional Value of Food*

Vitamin A deficiency causes half a million children to become partially or totally blind each year. Milled (white) rice is a common crop in many developing countries where rice serves as a main staple of the diet. However, rice does not contain adequate amounts of all necessary nutrients to prevent malnutrition and related disease. Milled white rice has had the husk removed, along with the stored beta-carotene. Researchers at the Swiss Federal Institute of Technology for Plant Sciences have created a strain of "golden rice" that has been modified to manufacture beta-carotene in the endosperm inside the grain. Stored beta-carotene can not be removed by milling of this transgenic food. Rapeseed (canola) has also been modified to contain high levels of beta-carotene, which is converted to vitamin A in the body.

#### *Disease Resistance*

Viral, fungal and bacterial diseases are extremely destructive to plant productivity, especially in the tropics. As a result, the genetic modification of plants to resist pathogens has been a priority for conventional plant breeders. Over the past decade, biotechnology has made it possible to increase the production of transgenic plants that are resistant to a variety of diseases. Many of these modified crop plants have been specifically designed for one region and the unique viruses that occur there. A major challenge for plant geneticists is to find virus-resistant genes that can not be easily overcome by the process of natural selection of the virus.

One potential advantage of genetic engineering is that it makes possible the transfer of multiple genes for disease resistance. Such a transfer of multiple genes would make adaptation of a pathogen more difficult. Engineering of multiple genes for disease resistance in crops requires advanced technological efforts, but it seems a logical, continued priority for food security. Golden rice has three added genes to increase the levels of beta-carotene: two from the daffodil, and one from a micro-organism.

#### *Herbicide, Pesticide Resistance*

Large-scale use of pesticides and herbicides is expensive and can potentially affect human health and damage the ecosystem. There is a pressing need to design herbicide and pesticide resistant crop plants for developing nations that can not afford the use of chemicals to enhance crop production. Reduced use of chemicals translates to reduced use of fuels to spray fields (Panos).

#### *Cold Tolerance*

Unexpected frost can destroy sensitive seedlings. An antifreeze gene from cold water fish has been introduced into plants such as tobacco and potato. With this antifreeze gene, these plants are able to tolerate freezing temperatures that would normally kill seedlings.

Transgenic strawberries are able to resist freezing temperatures down to 10°F.

#### *Drought Tolerance*

Drought is a major problem for nearly all crop plants, and the prospect of a "drought resistance gene" has generated much research. There are many traits that contribute to drought tolerance or resistance: long, thick roots; thick, waxy leaves; the ability to produce viable pollen during a drought; and the ability to recover from a dry period. Some of these traits can be controlled genetically, but more research is necessary for identifying desired genes (Kendall).

### *Salt Water Tolerance*

A salt tolerance gene from mangroves has been identified, cloned and transferred to other plants. The resulting transgenic plants were found to be tolerant to higher concentrations of salt. These transgenic plants may sustain croplands that have been compromised by salt water.

### *Removal of Toxins from Soils (Phyto-remediation)*

Soil and ground water pollution continues to be a problem in all parts of the world. A plant with the ability to remove substances such as nickel or zinc will usually only remove one element and will grow slowly. One way around these limitations may be to genetically engineer crop plants to more rapidly absorb toxic substances. Some increased metal tolerance has been obtained in transgenic *Arabidopsis* plants (Meagher). Currently, poplar trees have been genetically engineered to clean up heavy metals from contaminated soils. The use of plants for decontamination of soil is still at an early stage in development (Cunningham).

### Potential Risks of GM Crops

#### *Loss of Biodiversity*

Since the Green Revolution, researchers have documented that indigenous strains of wheat have virtually disappeared from India, Nepal, North Africa and Greece. Intensive plantings of successful Green Revolution strains have displaced native varieties that have been cultivated for centuries (Fowler and Mooney). Similarly, opponents of biotechnology believe that adoption of transgenic plants will lead to a reduction in biodiversity by the presence of superior GM crop seed. It is important to maintain indigenous plants, as this is where the genetic traits reside that may be needed for future recombinant genetics. Wild relatives of domesticated crops, known as 'landraces,' are frequently relied upon to replenish and maintain the vigor of domesticated crops.

Another consideration is reliance on a single plant strain could result in devastating results should a pathogen present itself and destroy the host plant. This was a reality during the Irish famine that killed one million people between 1845-1847. Irish farmers had become dependent on a single species of potato that was susceptible to a particular fungus.

#### *Centers of Crop Diversity*

Centers of crop diversity are regions around the world that harbor populations of traditional, related crop varieties (landraces) and their

wild relatives such as corn and its wild relative, teosinte. These wild populations constitute a reservoir of genetic material that can be moved into the crops by traditional breeding techniques and are the basis for the world's food supply. Centers of diversity are essential to the survival of world agriculture because landraces and their wild relatives provide the raw genetic material for breeding new characteristics into crops (Rissler). Breeders in need of new traits go to centers of diversity, where they may look for qualities such as disease resistance, cold tolerance, and drought resistance. Wild populations are the source of new genes that plant breeders and genetic engineers use to adapt crops to changing environmental conditions.

Areas of greatest diversity usually coincide with the center of origin, or where crops were first domesticated (Fowler and Mooney). Canada and the United States are the center of diversity for berries including blueberries, cranberries, raspberries, strawberries, and gooseberries. Mexico is the center of diversity for corn as well as the center of origin. Ethiopia is the center of diversity for wheat, even though wheat originated in the Middle East.

### *Health Risks*

Transgenic crops may pose risks to human health. Many children and adults have developed life-threatening allergies to various foods. There is a risk of transplanted genes producing proteins in the plants that may cause allergic reactions in susceptible individuals. Before an allergic reaction can occur, a person who is genetically predisposed to food allergies must consume a sufficient amount of an allergen. During digestion, the person's body produces antibodies to the allergen, but there is no allergic reaction upon initial exposure. It would take another exposure, possibly months later, before enough antibodies exist to trigger an actual reaction (Milloy).

In a recent scare involving taco shells made from Starlink corn, a GM crop, the Center for Disease Control acknowledged that the sampling from alleged sick people was too small to confirm or deny the existence of a true allergen to Starlink corn. Extensive testing of genetically modified foods will be required to avoid unanticipated side effects.

Another health issue with genetically modified foods is the potential for genes to produce resistance to antibiotics. Marker genes are attached to the target gene to identify cells containing the new gene element. When exposed to the antibiotic normal cells die, but those with the marker gene survive. The antibiotic resistant genes could be picked up by harmful bacteria, which would reduce the range of drugs

that can be used to treat disease. Genetic engineers have recognized this danger and the use of antibiotic resistance markers may be phased out (Panos).

### *Adaptation of Pests and Disease to GM Crops*

Insects, disease causing organisms and weeds are known to adapt to most pesticides and GM crop varieties that contain resistant genes. In some cases, adaptation occurs within one or two years. There is need for more research on transgenic plants that have been made resistant to local pests to assess their sustainability in the face of increasingly more virulent pests.

### *Cross Pollination by GM Crops*

As transgenic plants move from the research lab into the fields, there have been concerns of wind blown pollen drifting into neighboring non-modified crops. Bees and other pollinating insects should also be considered as movers of designer pollen. Pollen from GM herbicide-resistant plants could transfer to nearby related wild plants, giving them competitive advantage and turning them into "super-weeds" that could pose a threat to both wild and cultivated plants. Genetic pollution is a huge concern to farmers of organic crops.

### *GM Crops as Super-weeds*

GM crops have the potential to become pests or 'weeds' should their populations become uncontrollable and immune to traditional pesticides. Transgenic crops may be more competitive and displace indigenous or cultivated plants. This problem has occurred in Alberta, Canada where farmers report of canola plants displaying resistance to two different herbicides ([cropchoice.com](http://cropchoice.com)).

### *Unintended Harm to Other Organisms*

Certain types of transgenic crops have been engineered to manufacture their own pesticides and fungicides. It is expected that these plants will harm organisms other than their intended target. Little is known of the potential harmful effects to non-targeted organisms.

## Socio-Economic Implications of Genetically Modified Crops

### *The Role of Private Industry in the World's Food Supply*

Traditionally, agricultural research has been conducted in the public sector, usually by universities or governmental agencies. Information was accessible and risks and benefits were shared, often on

international levels. A new trend however, is the privatization of agricultural research and patenting of successful GM seed stock by huge biotechnology firms. Desirable crop seed is still available to farmers, but there are often contractual limitations that are now part of the sale. Patenting crop seed privatizes what used to be the common inheritance of future generations. Consequently, failure to do so denies biotechnology companies their intellectual property rights.

The world market for agricultural seed is worth an estimated \$45 billion a year. One third of this seed is produced commercially, one third is produced by governments or publicly funded institutions, and the remaining one third is the value of the seed saved by farmers for their own use in future crops (Panos).

A few large corporations are dominating the production of commercial seed. In 1998, it was estimated that the top ten seed companies control 30 - 40 percent of all seed sales. Monsanto, DuPont, Dow Elanco, Novartis, AgrEvo and Zeneca dominate the commercial development of GM crops. The efforts of these companies have so far been concentrated in high-volume crops that offer the best opportunity for sales large enough to recoup research costs and generate profits. The main targets have been soy beans, corn, cotton, rapeseed, potatoes and tomatoes.

### *Monsanto - An Example of Vertical Integration in the Biotechnology Industries*

Vertical integration occurs when all levels of production are controlled in generating a product. These levels include the raw product, research and development, manufacturing, marketing and distribution. Monsanto is an excellent example of vertical integration (and monopoly) of an industry. Founded in St. Louis, Missouri in 1901, Monsanto has produced a variety of chemicals, including saccharin for Coca-Cola, aspirin, plastics, textiles, Agent Orange, and the highly successful herbicide Roundup.

In the mid-1980's, Monsanto branched out into the "life sciences" (food ingredients, pharmaceuticals, plant genetics, etc.). Since 1996, Monsanto has spent over \$8 billion acquiring seed and agricultural-biotechnology companies. After its 1998 merger with American Home Products, Monsanto became the world's largest agrochemical firm, the second largest seed company, fourth largest in pharmaceuticals, and among the top five research companies in veterinary medicines. Monsanto's presence in so many areas of scientific research is cause for concern.

## *Marketing Strategies of GM Seed*

Biotech supply companies employ a variety of marketing strategies, claiming that the fees collected from the sale of GM seed will help to fund new research and development, increase the supply of seed, pay for educational programs, crop insurance, and activities focused on the global acceptance of agricultural biotechnology.

Monsanto, for example, uses restrictive contracts called "growers agreements," the terms and conditions of which must be accepted to use the technology. The growers receive the right to purchase the seed, but are not permitted to keep it, sell it or give it away for replanting purposes.

Pricing of some GM seed can be broken down into three components: the technology fee, the seed price, and the herbicide price. Monsanto (1998) says technology fees represent the value of the gene technology delivered via the seed. In 2002, Monsanto has agreed to eliminate technology fees in order to simplify the pricing for corn and soybean traits produced through biotechnology. Instead, growers will make a single payment to the seed company for technology and seed, rather than a payment to the seed company and a separate payment to Monsanto for the right to use their patented technology.

Another marketing strategy is the use of "bundling." In order to get one product, there must be the purchase of a second product, as in the case of Roundup herbicide and Roundup Ready seed. This technique also ties a client more closely to the supplying firm. The supplier has more opportunity to add special features, services and options (Goldsmith).

### *Terminator Technology*

The marketing of sterile seeds, or "terminator technology," is one of the most controversial agricultural biotechnology marketing strategies. Biotechnology has made it possible to sterilize crop seed, making it impossible for farmers to keep seed from the best plants to be replanted the following year. Currently 80% of crops in the developing world are sown using farmer-saved seed (Panos). Biotechnology firms that supply the seed argue that their product patents cover the seed and should not be used without their permission. Farmers are forced to purchase all of their seed each year, not an option for farmers in developing countries.

### *Genetic Mining (Bio-piracy or Bio-prospecting)*

One sector of biotech research is the hunt for new genes. Genetic mining is the practice of biotech companies traveling abroad

(generally to the Southern Hemisphere, where the greatest varieties of genes are found) and searching for new genes or new gene traits. Companies are rushing to claim patents not only on newly invented processes but also on newly 'discovered' genes used in those processes and on the knowledge of their properties. Monsanto was reported to be recruiting company employees "who are traveling somewhere exotic and wouldn't mind digging up a few soil samples for the sake of science" for Monsanto's agricultural screening programs. "You never know what you're going to find or where you are going to find it...Nothing's off limits," said Monsanto spokesperson, Margann Miller-Wideman (Heine).

These imported genes are then copied, recombined with a target plant, and claimed as intellectual property. The new genome is patented; seed is developed, and frequently sold back to the nation where the original plant has been grown for centuries. The mining of genetic resources is ongoing and difficult to control.

### *Patenting Life (Intellectual Property Rights)*

Thomas Jefferson introduced America's first patent act over 200 years ago. A patent is a legal claim over an idea for an invention that gives the holder exclusive rights to profit from it for a set number of years. Permission for public use of the invention is granted by paying the patent holder license or royalty fees. To be granted a patent, an applicant must be able to prove:

1. Novelty: It must be a new idea, not known or used by anyone before.
2. Use: The patent application must explain what the invention is to be used for and why.
3. Inventiveness: It must involve an inventive step that is "non-obvious."

Until recently, these criteria excluded living organisms, which were always regarded as discoveries of nature and not able to be patented (Anderson).

In 1930, the Plant Patent Act was implemented and provided a 17-year protection period for new varieties of asexually reproduced plants. Asexually reproduced plants are those which are commercially propagated by cuttings or grafts, such as fruit tree varieties and roses. Asexually produced plants are basically clones; many varieties had been around for a long period of time, then were suddenly patented by the "discoverer." Sexually reproduced plants, which require a certain amount of human intervention to create desired effects such as color, sweetness, or hardiness, were not covered by this dubious legislation.

The Plant Patent Act of 1930 did not recognize the individual inventor or the creative act of experimental plant breeding as much as it recognized and rewarded the system that produced the new variety, whether by luck or design (Fowler, 1994).

In 1980, the US Supreme Court ruled that a life form could be patented. In the landmark case of *Diamond vs. Chakrabarty*, Chief Justice Warren Burger declared that the "relevant distinction is not between animate and inanimate things but whether living products could be seen as human-made inventions." The case involved the right to patent a bacterium that digests crude oil. But can a living organism be properly regarded as a human invention? Ananda Chakrabarty, design engineer of the bacterium, admitted that he "simply shuffled genes, changing bacteria that already existed - it's like teaching your cat a few new tricks." (Brel).

In 1985, the US Patent and Trademark Office extended the Chakrabarty ruling to allow for the patenting of genetically engineered plants, seeds and plant tissues. The boundaries of patent law continue to be pushed every year. Life industries are staking territorial claims to cover entire species of flora and fauna, consolidating their dominant position as a means to block research and competition (GRAIN). According to the *Wall Street Journal*, in the United States at least one company has been created whose "main business is buying up broad patents and then suing other companies for alleged infringement." (Lambert). It seems unreasonable that a company can make a single genetic alteration to a plant, and claim private ownership to it as their invention, when the very plants that are being engineered result from thousands of years of careful selection and breeding by farmers around the world.

#### *Displacement of Foreign Crops by American GM Crops*

GM crops can be modified to contain desired traits found in foreign crops. In 1995, US farmers harvested the first commercial crop of a rapeseed (canola) plant modified to contain lauric acid, an important material in the soap and cosmetics industry. Lauric acid is a natural ingredient of palm and coconut oil, for which the Philippines and Indonesia supply 80% of the world market. If the market for one of their main export crops disappears, the livelihood of up to 30% of the Philippine population would be impacted (RAFI).

Calgene, the producer of the modified rapeseed plant, maintains that the new variety is not intended to replace palm oil, but to be grown as a buffer in years when the tropical oil is in short supply. Others are less sure: "The biotechnology industry says it will feed hungry people and increase productivity in the Third World. The truth is, it may have

devastating impacts on the poor people of the Third World," says Hope Shand, research director of Rural Advancement Foundation International.

Another concern by critics of the GM seed industry is that few GM crop varieties available are likely to be used to feed local people in developing countries. Environmental campaigner George Monbiot points out that GM corn was developed primarily as animal feed. If it is grown in Africa it will be for production of meat to be eaten by local elites or exported to developed nations. Producing animal feed "is one of the engines of African famine, as land that was previously devoted to meeting local people's food needs has now been expropriated to supply the world's appetite for animal protein."

### *Dependency of Developing Nations on GM Seed*

Developing nations that use GM crop seed may find themselves caught in a downward spiral of foreign dependency and loss of native species of food crops. Reliance on biotechnology corporations for seed may also result in the loss of indigenous crop plants.

Crop seed could also be used as leverage against foreign nations should political conflicts arise. Many nations are concerned about becoming dependent on American-made GM seed because that seed could be withheld if an international crisis with the US should arise. GM seed makes it more likely that food could become a weapon (Moy).

### Who Is Regulating Genetically Engineered Crops and Foods?

Governments around the world are working to establish a regulatory process that monitors the effects of GM crops on the environment and human health. Many developing nations lack the political and technical infrastructure to establish a regulatory process, and rely on the originating countries for their testing approval of a GM food.

The US has the most experience with regulating GM foods, and they also have the most clearly defined "science-based" evaluation process (McHughen). However, the regulatory process of GM foods can be confusing because there are three different government agencies that have jurisdiction in the US:

1. The EPA (Environmental Protection Agency) evaluates GM plants for environmental safety. They also regulate new pesticides being used in GM crops.
1. The USDA (US Federal Department of Agriculture) evaluates whether GM plants are safe to grow. They also regulate the importation of products of genetic engineering, and determine if

they represent a risk of becoming a pest (weed).

2. The FDA (Food and Drug Administration) evaluates whether a plant is safe to eat.

In May 1992, before the first transgenic foods came onto the market, the FDA determined that most of the foods produced by genetic engineering should be regarded and regulated as if they were foods produced by traditional methods. This means that genetically engineered foods in the US do not require a pre-market approval process, publication notification, or labeling. Food industry decides when and whether to consult with the FDA, and it is the industry that conducts its own safety tests for their own products, notifying the FDA only if they suspect a problem.

### Environmental Activist Groups

Although environmental groups can not regulate GM foods, they do influence public opinion through well-meaning educational campaigns. Activist groups may not have the scientific knowledge or communication skills to convey their legitimate concerns. The media is easily manipulated by environmental groups' imaginative stunts that often coincide with biotechnology conventions or other high profile conferences. Unfortunately, unbiased scientific data from reliable experts is often overlooked for the more emotional and insubstantial "sound bytes" of information on the 6:00 news.

### *Labeling of GM Foods*

When people began to realize they were eating genetically engineered food without their knowledge or consent, there were immediate demands for segregation and labeling of GM food. Surveys showed that the vast majority of people wanted comprehensive labeling of GM food, even if they did not mind eating it. It was also argued that labeling would be essential in order to trace any health issues that may occur. Consumer interest groups are demanding mandatory labeling designed to clearly convey accurate information in simple language. They believe people have the right to know what they are eating.

For the most part, agribusiness industries believe that labeling should be voluntary and influenced by the demands of the free market. If consumers show preference for labeled foods over non-labeled foods, then industry will have incentive to regulate itself or risk alienating the customer. However, self-compliance with existing safety regulations is not always reliable.

### **Implementation**

## Vocabulary

bioinformatics- The discipline concerned with the management of genetic data.

budding- A form of grafting. A twig containing a bud from a desired tree is physically joined to another tree by inserting the twig under the bark of the root stock tree.

cultivar- A hybrid plant or a transgenic plant.

DNA (Deoxyribonucleic acid)- The structure of living things. Each gene is made up of segment of DNA. The total DNA of a cell comprises the genome.

gene flow-The transfer of genes from altered crops to weedy relatives by way of cross pollination.

grafting- A form of plant cloning. A twig from a desired tree is physically joined to an existing root stock. The above ground portion of the tree will be a clone of the tree that the twig was removed from.

hybrid- The offspring of two parents differing from each other in one or more genes.

landraces- Wild relatives of a traditional crop, such as wheat.

marker gene- Genes that are used to detect successfully transformed cells.

rDNA- Allows scientists to cut and make copies of a bit of one organisms gene code and paste that gene into another organisms' genome.

substantial equivalence- If a GM food and a non-GM food are equivalent in all characteristics that are of importance to consumers (safety, nutrition, flavor, and texture) the GM food is said to be

substantially equivalent.

transgenic- Refers to an organism that has been genetically modified.

## **Teaching Strategies**

The following instructional strategies are designed for high school students with gifted abilities. The lessons will be part of a Contemporary Issues class and will require students to be avid researchers and critical thinkers. Students will evaluate the many implications of genetically modified crops.

## **Critical Thinking: Social Studies, Science and Health**

### **Brainstorming**

Materials: Butcher paper, markers.

Objectives: To get students to think out loud and to record their responses.

Procedures: Ask the following questions and record responses on butcher paper.

1. What do you know about genetically modified plants or genetically engineered foods?
2. Have you consumed any genetically engineered foods lately?
3. What benefits might be gained through genetically modified crops?
4. What environmental or health risks might occur as a result of genetically modified crops and their subsequent foods?

### **Research**

Students will select a topic and generate a short research paper that contains political, social and ethical issues regarding the following (or other related) topics. Students will need a bibliography and citations should be done in MLA style.

Materials: Internet access, library books, primary sources, MLA style book

Objectives: Gather information, learn the facts, present the information in a short research paper.

Procedures: Allow students to select a research topic from the following list of issues.

Students will use a variety of sources to gather their

information. Encourage students to obtain information through primary sources when possible. Review correct use of citations for the bibliography.

1. Do we need to protect threatened species and biodiversity?

Students will investigate the ramifications of lost biodiversity. Wild relatives of a domesticated plant are frequently relied upon to strengthen the cultivar's genes. Students will also research the evolution of a present day food plant such as corn or lettuce and look for the number of varieties that have become extinct.

2. Do plants have rights?

Students will investigate the applicability of the concept of a "right." Are insentient beings representable of needing rights? Does a species without awareness, expectations, or interests merit rights?

3. Investigation of the steps involved with isolating, copying and recombining DNA.

Students will research the technology required to engineer a new genome.

4. Investigation of how GM foods are tested for toxicity in humans.

Students will contact the FDA (etc...) for protocols in assessing a GM food plant for safety.

5. Investigation of one GM food plant.

Students will trace the evolution of a GM food plant and will identify health risks and benefits of these modifications.

6. Investigation of risks to ecosystem from GM crops.

Students will research the actual and potential environmental problems associated with GM crops.

7. Examination of ethical implications of genetic mining (bio-piracy).

Students will investigate the pilfering of developing nations' indigenous biological resources by large American corporations. There are serious concerns that these companies are being granted patents for products and technologies that make use of plant species from other countries. Students will contact environmental activist groups for information.

8. Investigation of corporate patents (and subsequent lawsuits) on existing life forms. Students should review the Plant Patent Act of 1930 as well as the Plant Variety Protection Act of 1970. What are the boundaries of intellectual property? Growers can be sued if their crops contain the genes from patented transgenic plants and they did not buy the designated GM seed. (see [cropchoice.com](http://cropchoice.com))
9. Investigation of labeling of genetically modified foods.  
Students will examine how GM foods are identified so consumers can make informed choices. GM strawberries containing DNA sequences from winter flounder may be of concern to vegetarians. What labeling laws are in place to inform consumers here in the US?
10. How will developing countries access GM technology?  
Students will investigate the proliferation (if any) of GM crops in developing countries. Nations that most need this technology may be least able to afford it. How magnanimous are the giant corporations that control the patents on successful GM crop seed?
11. Assessment of a country's present food challenges.  
Students will investigate the food challenges of a country and the GM crops that could potentially help with regard to quantity and quality of crops.
12. Evaluation of propaganda from environmental activist groups.  
Students will request corporate annual reports from agrochemical companies as well as propaganda from environmental activist groups. Students will evaluate propaganda vs. corporate annual reports. How do these corporations view themselves? Is the negative press warranted? Do opponents of GM crops have valid concerns?
13. Investigate "Centers of Diversity."  
Students will research Centers of Diversity (regions around the world that collect populations of related crop species). Centers of Diversity constitute a reservoir of genetic material that can be moved into crops by traditional breeding techniques.
14. Comparison of the Green Revolution with the "Gene Revolution." Students will compare and contrast the social and scientific outcomes of these agricultural periods.
15. Investigation of transgenic plants as producers of vaccines or medicines.

Students will investigate the pharmaceutical potential of genetically engineered plants. Several major medicines have been produced from botanical sources (aspirin, digitalis, and quinine). What can pharmaceutical companies expect from transgenic plants?

16. Investigation of unwanted population growth as a result of more (GM) food.

Students will evaluate the possibility of an increasing world population as food security is realized for all nations. Did the Green Revolution have an impact on world populations? Will a burgeoning world population obliterate our limited natural resources?

## **New Mexico State Standards**

### Language Arts

- 1) Student will listen to, read, react to, and analyze information.
  1. Student will synthesize and evaluate information to solve problems across the curriculum.
  2. Student will demonstrate critical thinking skills to evaluate information and solve problems.
  3. Student will demonstrate competence in the skills and strategies of the writing process to inform and persuade.
  4. Student will compose written arguments that develop and support informed opinions  
by: stating a progression of ideas; selecting appropriate style; tone and use of language for a particular effect; describing and analyzing personal, social, historical, or cultural influences; presenting rhetorical strategies to support proposal.

### Global Connections and Technology

- 1) Student will analyze the influences of science and technology upon society.
- 2) Student will evaluate how science and technology have transformed the physical world and human society.
- 3) Student will analyze how science and technologies influence and

are influenced by core values, beliefs, and attitudes of society, including public policies.

4) Student will examine the complex conditions and motivations which contribute to conflict, cooperation, and interdependence among groups, societies and nations.

5) Student will analyze and assess the causes, consequences, and evaluate possible solutions to persistent, contemporary and emerging global issues.

6) Student will evaluate the concerns, standards, issues and conflicts related to universal human rights and their impact on public policy.

7) Student will evaluate roles of national, international and multinational organizations on international issues.

8) Student will compare and evaluate relationships and tensions between national sovereignty and international interests in such matters as territory, economic development, use of natural resources, nuclear, and other weapons and concerns about human rights.

### Science

1) Student will interpret evidence to understand changes in natural and artificial systems.

2) Student will evaluate the interaction of multiple factors such as risk, environment, and desires on choices for meeting basic human needs.

### **Reading List for Students**

Linda Tagliaferro. *Genetic Engineering: Progress or Peril?* 1997.

Discusses current and potential uses of genetic engineering in fields such as medicine, criminal investigation and agriculture.

Genes Linda Tagliaferro and Mark V. Bloom, Ph.D. *The Complete Idiot's Guide to Decoding Your* 1999.

Explains the history, applications and future vision of genetics.

Nicholas Wade. *The Science Times Books of Genetics* 1998.

New York Times science reporters interpret and translate the science and applications of genetics. Includes topics such as Building New Organisms & Genes and Life Spans.

Lisa Yount. *Genetics and Genetic Engineering* 1997.

Profiles geneticists and examines the discoveries they have made.

## **Web Sites for Students and Teachers**

Biotech Basics (sponsored by Monsanto)

<http://www.biotechknowledge.com/>

Gaia Foundation <http://www.foundationgaia.plus.com/>

Genetic Resource Action International (GRAIN)

<http://www.grain.org/front/index.cfm>

International Food Information Council <http://ificinfo.health.org>

*A Science Odyssey: People and Discoveries* <http://www.pbs.org>

*Techniques of Plant Biotechnology* from the National Center for Biotechnology Education

<http://www.ncbe.rdg.ac.uk/NCBE/GMFOOD/>

United Nations Food and Agriculture Organization

<http://www.fao.org>.

Women's Environmental Network <http://www.wen.org.uk/>

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