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Controversial Issues Regarding the Consumption of Genetically Modified Crops

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Introduction

As we move into the twenty-first century, careers in biotechnology, nanotechnology, mathematics and engineering are becoming increasingly more important. This is especially true in the fields of medicine, agriculture and industry. As a result, a greater number of students with undergraduate and/or graduate level university degrees will be required to fill the numerous and varied professional opportunities which are currently being developed in these disciplines. However, the technologies and the outcomes generated from such technologies in these fields have sparked a number of contentious debates around the world. This curriculum unit is intended to be part of an environmental science program for students in the eleventh or twelfth grade. Using scientifically sound concepts and principles, the students will debate a number of societal issues regarding the consumption of genetically modified crops. One of the major goals of this curriculum unit is to improve the critical thinking and reading comprehension skills of the students while examining current environmentally important problems. It is also designed to provide the students with a basic understanding of the methodology and techniques inherent to genetic engineering.

Student Demographics

Founded in 1848, the Philadelphia High School for Girls is a college preparatory, special admit high school. It is also the only single sex public school in the city of Philadelphia. The enrollment consists of approximately 1,000 female students in grades 9 through 12. The breakdown of this culturally diverse student population is as follows: 66 percent of the students are African American, 16.6 percent are Asian, 8.7 percent are Latino, 7.7 percent are Caucasian, and 1.0 percent is listed as other. The admission requirements for the students include: scoring above the 85th percentile on standardized tests, and receiving scholastic grades of all A's and B's with no more than one C. In addition, the students must have good attendance and behavior records.

Objectives

Personal observations as a high school science teacher spanning a twenty-seven year career with the School District of Philadelphia has led me to the conclusion that academic achievement in the sciences, whether in the life sciences or the physical sciences, is directly related to a student's ability to read and comprehend grade level informational text. This is in total agreement with the Pennsylvania Common Core State Standards. Within each common core standard are anchor standards which students should be able to achieve within each grade level. For example, students in grades eleven and twelve should be able to: "Synthesize information from a range of sources into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible". [1] The Office of Curriculum, Instruction, and Assessment of the School District of Philadelphia has recently prepared a resource booklet that outlines strategies which support the goals of the common core standards. With regard to literacy, the emphasis is on instructional reform. More specifically, one of the instructional reforms requires the use of nonfiction informational text in grades K-12 in order to improve content based knowledge. [2] As a result, this curriculum unit will examine the current literature regarding the generation, consumption and the various concerns of genetically modified crops. Therefore, the primary goal of this unit is improve the critical thinking and reading comprehension skills of my students in three environmental science classes while presenting the fundamentals of genetic engineering.

Rationale

Genetic engineering is the process of artificially changing an organism's genetic information. The outcome or product of such technology results in a genetically modified organism. The consumption of genetically modified plants and/or animals is one of today's most controversial issues facing society. This curriculum unit is designed to examine the arguments for and against the global use of genetically modified crops. It is intended to be a two week unit in three environmental science classes comprised of eleventh and twelve grade students with the expectation of introducing it during the unit on "Food and Agriculture".

Background Information

The term genetic engineering can be rather intimidating especially to those who have an aversion to science. However, genetic engineering is simply a systematic process whereby the genetic information of an organism is altered. It is the process of producing a genetically engineered organism which is complex. The remainder of this section will be devoted to an overview of genetics and genetic engineering. Included in this section will be summaries dealing with: 1. genetics, 2. the various techniques availabe for the generation of genetically modified crops, and 3. the controversial issues concerning the consumption of genetically modified crops.

Genetics

Gregor Mendel has long been regarded as the father of modern genetics for his work on inheritable characteristics or traits in pea plants during the mid-nineteenth century. His numerous and thorough observations were the basis for two laws or principles of genetics. Mendel's first law, the principle of segregation, refers to the separation of individual alleles within a given trait during meiosis. The second law, the principle of independent assortment, involves the ability of alleles from different traits to separate independently of each other during meiosis. [3]

Although Mendel's laws of inheritance were sufficient to explain his observations with pea plants, the exact nature of the genetic material remained unclear until the middle of the twentieth century. Then in 1952, Alfred Hershey and Martha Chase performed the following experiment. Initially, they grew viruses in the presence of either ^{32}P or ^{35}S. These radioactive isotopes were chosen because ^{32}P labels only the DNA within the virus whereas ^{35}S labels only the outer protein coat of the virus. After infecting E.coli with the radioactive viruses, they were incubated for some time before being separated. Their results indicated that for those viruses grown in the presence of ^{35}S, the radioactivity remained in the liquid or the protein coat fraction. However, for the viruses labeled with ^{32}P, the radioactivity was localized in the fraction containing the bacterial debris. These results definitively demonstrated that DNA was the genetic material and not protein as was previously thought by many researchers. [4, 5]

The key to understanding the transmission of hereditary information was unclear until the three dimensional structure of DNA was determined by James Watson and Francis Crick in 1953. Applying the findings of Erwin Chargaff together with the X-ray diffraction patterns published by Maurice Wilkins and Rosalind Franklin, Watson and Crick were able to demonstrate the B-helical, anti-parallel structure of DNA. Chemically, DNA consists of two polynucleotide stands connected together by hydrogen bonds. Each nucleotide consists of a five carbon sugar, deoxyribose, covalently bonded at the 5' carbon position to a phosphate group by way of a phosphodiester bond and covalently bonded to a nitrogen base at the 1' carbon position. Each nucleotide is then covalently bonded together by linking the 5' phosphate group of one nucleotide to the 3' hydroxyl group of the next nucleotide, again with a phosphodiester bond. The nitrogen bases present in DNA are adenine, thymine, guanine and cytosine. Whereas adenine and guanine are purines, thymine and cytosine are pyrimidines. According to Chargaff's rules, in DNA the adenine on one polynucleotide strand will form two hydrogen bonds with a thymine base on the other polynucleotide strand. Similarly, guanine will always form three hydrogen bonds with cytosine. The bonding between a purine and a pyrimidine is important in explaining the 2 nm width between nucleotide strands. [6, 7, and 8]

In their landmark paper, Watson and Crick stated, "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material." [9] Thus, the detailed three dimensional structure of DNA laid the foundation upon which molecular biology and molecular genetics are based. The central dogma of molecular biology, which was originally explained by Francis Crick, states that DNA is transcribed to produce RNA which is then translated to form protein. [10] The following will serve as a very superficial review of transcription and translation. In eukaryotic cells, the DNA is localized in the nucleus with the exception of the mitochondrial DNA. Since the DNA is much too large to pass through the nuclear membrane, the cell must have a mechanism whereby genetic information can get into the cytoplasm. Therefore, the purpose of transcription is to transport genetic information from the nucleus into the cytoplasm where proteins can be synthesized. In order to generate an mRNA molecule one must transcribe a particular gene from a DNA template. Since the details of transcription differ somewhat between prokaryotic and eukaryotic cells, only the general sequence of events will be mentioned. Initially, the double stranded DNA must be accessible for transcription. This is accomplished by the binding of the enzyme RNA polymerase to the promoter region of the gene. This binding opens up that DNA fragment allowing transcription to begin. As the template becomes accessible, complementary nucleotides are added to the growing mRNA molecule in the same 5' to 3' direction as in DNA replication. Once the gene has been transcribed, the mRNA molecule undergoes modification by the removal of introns. The remaining exon portions are spliced together forming a completed mRNA molecule. [11]

The process of synthesizing a protein molecule from mRNA is known as translation and occurs in the cytoplasm of eukaryotic cells in a 5' to 3' direction. The mRNA contains the sequence of nucleotide bases which code for a specific amino acid. Each code or codon is comprised of three nucleotide bases and is therefore referred to as a triplet code. There are actually 4^3 or sixty-four possible codes for twenty different amino acid. This means that there is a slight degree of freedom which occurs in only the last base of the code. Francis Crick originally referred to this as the wobble hypothesis in 1966. [12] For that reason the genetic code has also been referred to as a degenerate code. It should be mentioned that in RNA molecules uracil replaces thymine as the complement of adenine. It is also important to mention the structural differences between mRNA and tRNA. Whereas mRNA is a linear molecule that contains the triplet code, tRNA is shaped more like a clover leaf with the anticodon on one side of the molecule and the specific amino acid attached to the opposite side. Another difference between the two types of RNA involves the wobble hypothesis. The third base of the anticodon can also exhibit a slight degree of freedom with regard to its third anticodon base. The following table shows the possible complementary bases in the third position of a tRNA molecule for both prokaryotic and eukaryotic cells. Inosine, indicated by the letter I, is a metabolic derivative of guanine.

Prokaryotic Cells		**Eukaryotic Cells**	
wobble codon	possible anticodon	wobble codon	possible anticodon
U	A, G, or I	U	G or I
C	G or I	C	G or I
A	U or I	A	U
G	C or U	G	C

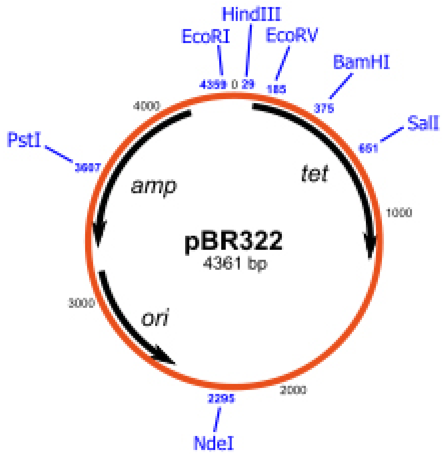
Additionally, these differences between prokaryotic and eukaryotic cells with regard to the possible anticodon bases are believed to be due to differences in their ribosomal structures. Once inside the cytoplasm, the mRNA binds to a ribosome and protein synthesis commences. The ribosome has three tRNA binding sites, the A-, P- , and E-sites, which are all involved in the synthesis process. The abbreviations stand for aminoacyl-tRNA, peptidyl-tRNA, and exit. The process involves the binding of an aminoacyl-tRNA complex to the A-site of the ribosome. The aminoacyl-tRNA complex is formed by an enzymatic reaction involving aminoacyl-tRNA synthase which binds the tRNA to its specific amino acid. Once formed the aminoacyl-tRNA complex can bind to the A-site. Peptidyl-transferase catalyzes the formation of a peptide bond between the growing polypeptide chain-tRNA complex now at the P-site and the aminoacyl-tRNA complex at the A-site. At this point the tRNA at the A-site moves to the P site while the tRNA at the P site moves to the E site and exits the ribosome. This process continues until the polypeptide chain is completed. After completion, the polypeptide chain undergoes a number of modifications before forming the final protein molecule. [13, 14]

Recombinant DNA Technology

The removal and subsequent insertion of specific genes or DNA fragments from one organism into another is the basis of recombinant DNA technology. Genetic engineering utilizes this technology in creating genetically modified organisms. The initial step is to isolate the DNA region of interest such as a gene for a particular protein. This is achieved with the aid of a specific type of enzyme known as a restriction endonuclease. These are bacterial enzymes that cut the DNA between specific nucleotide sequences called the recognition sites which can range anywhere from four to eight nucleotides in length. These enzymes are named after the genus, species and strain of bacteria from which they were isolated. These enzymes have the ability to produce one of three different types of cleavage ends: blunt ends, 3' sticky ends, or 5' sticky ends. There are three basic types of restriction endonucleases, types I, II, and III. Each of which has its own unique properties and functions. The most commonly used restriction endonucleases, however, are of the type II variety. The following table lists several type II restriction endonucleases, their recognition sequences, and the type of cleavage segments they produce.

Enzyme	**Recognition Sequence**	**Ends**
BamHI	5′ -GGATCC- 3′	5′
Eco RI	5′ -GAATTC- 3′	5′
HaeIII	5′ -GGCC- 3′	Blunt
HpaI	5′ -GTTAAC- 3′	Blunt
PstI	5′ -CTGCAG- 3′	3′
Sau3A	5′ -GATC- 3′	5′
SmaI	5′ -CCCGGG- 3′	Blunt
SstI	5′ -GAGCTC- 3′	3′
XmaI	5′ -CCCGGG- 3′	5′

The ability to transmit the DNA isolated from one organism into that of another requires the use of a vehicle or vector. Commonly used vectors for this purpose are plasmids, which are extra-chromosomal bacterial circular DNA. The following diagram illustrates a commonly used plasmid showing the restriction map. The process of genetic engineering involves the following



http://en.wikipedia.org/wiki/PBR322

basic steps. The plasmid is treated with the same restriction endonuclease that was used to isolate the gene of interest. The gene is inserted into the plasmid by virtue of their similar sticky ends. The recombined plasmid is grown in the presence of the bacteria within which it replicates independently of the chromosomal DNA thereby amplifying the gene of interest.

15, 16, and 17

History of Genetically Modified Crops

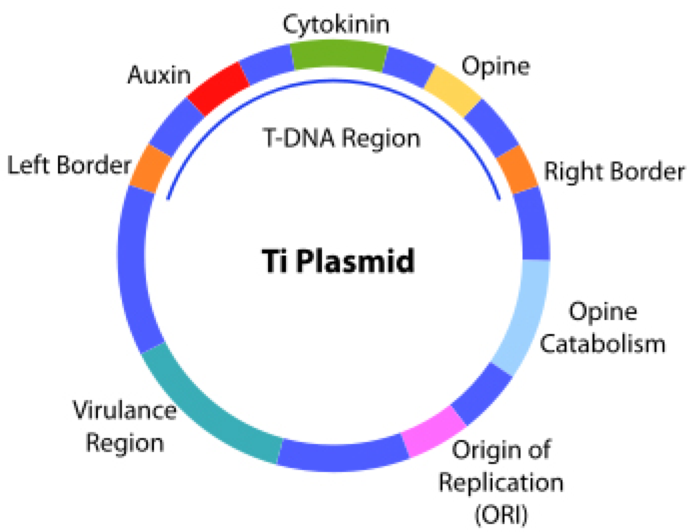
Genetic engineering is a process by which the genetic material of an organism is artificially altered. The first genetically modified plant was produced by Monsanto in 1982. [18] It was an antibiotic-resistant tobacco plant. Twelve years later, in 1994, the first genetically modified plant approved by the Food and Drug Administration for marketing in the United States was a tomato plant which was selected for delayed ripening. [19] By the year 2000, six private companies in the United States held slightly over 1000 patents in agricultural biotechnology. They included: Monsanto (287), DuPont (279), Syngenta (173), Dow Chemical (157), Aventis (77), and Savia (33). [20] In 2010 the United States planted the most genetically modified crops in the world. It was reported to be on the order of 66.8 million hectares which equates to approximately 165 million acres. This was 2.6 times the amount of second largest producer, Brazil. Among the genetically modified crops planted in 2010 were: alfalfa, cotton, maize, papaya, rapeseed, soybeans, squash, sugar beets, sweet peppers, and tomatoes. [21] Of all the soybeans, cotton and corn produced in the United States in 2013, an astounding 91% of the soybeans, 88% of the cotton, and 85% of the corn were genetically modified. [22] The role of genetic engineering is becoming increasingly important and will continue to increase. It has been reported that between the years 1996 and 2010 there was an 80 fold increase in the amount of genetically modified crops planted. [23]

Techniques Availabe for the Generation of Genetically Modified Crops

The United Nations Department of Economic and Social Affairs published a report in 2004 projecting the world population up to 2050. They estimated that from a global population of 6.1 billion in 2000 there would be an approximate 47% increase to about 8.9 billion in 2050. [24] Therefore, the development and application of genetic engineering and in particular genetically modified foods will be of substantial importance in meeting the global concerns in twenty-first century regarding world hunger. With genetic engineering, specific genes of interest can be inserted into plants. Just a few of the benefits of this technology include: improving the quality, appearance or taste of the crop, improving the yield of the crop, and producing crops which are resistant to pests, disease, or herbicides. [25] As of 2012, the genetic engineering techniques currently being used or under development for use include: agro-infiltration, cisgenesis, intragenesis, oligonucleotide-directed mutagenesis, zinc-finger nuclease technology, RNA-dependent DNA methylation, grafting onto genetically modified rootstock, and reverse breeding. Of these, the first five are the most commonly used techniques in producing genetically modified crops to date. [26]

Agro-infiltration

The bacterium *Agrobacterium tumefaciens* has been widely used for designing transgenic plants. This bacterial species contains the Ti plasmid which produces crown-gall tumors in plants when infected by the bacteria. The Ti plasmid ranges in size from about 140 to 235 kb in length. Within the circular DNA Ti plasmid, is a DNA section known as the T region which is on the magnitude of 15 to 30 kb in length and contains several genes for the production of tumors. The illustration below shows the various regions within the Ti plasmid. Since the Ti plasmid is too



http://en.wikipedia.org/wiki/Ti_plasmid

large to be used as a vector, a method called cointegration must used for genetic modification. This method involves the use of two smaller recombinant plasmids. One of the plasmids contains the gene of interest which is then inserted into the other plasmid containing portions of the Ti plasmid (Ti-based vector). Together they form a non-pathogenic cointegrated Ti plasmid. The bacteria containing the cointegrate Ti plasmid is grown in culture with pieces of plant tissue. If successful, the bacteria will insert the plasmid into the plant cells which then take root. Genetically modifiied crops created by agro-infiltration include: tomato, tobacco, white clover, lettuce, rice, and potato. [27, 28, 29]

This technology has been widely used to create crops that are resistant to the herbicide Roundup. In 2006, the molecular mechanism for this resistance was reported by a research group headed by Todd Funke at the University of Kansas. Roundup Ready plants, as they are termed, contain a gene that is insensitive to glyphosate. This herbicide affects the biochemical pathway for the synthesis of aromatic amino acids such as phenylanine, tryptophan, and tyrosine in plants. It specifically inhibits the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSP synthase) in the shikimic acid pathway. This is the enzyme which catalyzes the conversion of shikimic acid 3-phosphate to 5-enolpyruvylshikimate-3-phosphate. This biochemical step occurs immediately before the synthesis of chorismate from which the aromatic amino acids are derived. It is believed that the Roundup Ready plants contain the gene that codes for the enzyme (EPSP synthase) which is resistant to glyphosate. This enzyme resistance is believed to be the result of an alanine substiution for glycine at position 100 in the protein. [30, 31]

Cisgenesis/Intragenesis

Genetic modification by transgenesis involves the insertion of a foreign gene into a totally unrelated plant. As such this technology has many critics and a number of environmental concerns. It is believed that cisgenesis, however, offers distinct advantages over the use of transgenesis. This technique has fewer environmental concerns since this particular genetic modification could occur naturally due to the closely related species involved. There has been considerable debate over the exact definition of cisgenesis, but the current definition refers to a complete gene including the promoter, introns, and terminator regions that have been isolated from a sexually compatible species. A major difference between cisgenesis and intragenesis is that intragenesis involves using only portions of the cisgene. The same type of *Agrobacterium*-mediated transformation that is used for transgenesis is employed in cisgenesis/intragenesis. As of 2012, it has been reported that potato, apple, and melon have produced using cisgenesis or intragenesis. [32]

Grafting

The grafting of a nongenetically modified scion with a genetically modified rootstock offers another viable alternative to transgenesis. The scion is that portion of the graft which will determine the final characteristics of the fruit whereas the rootstock will convey its growth characteristics such as resistance to herbicides, disease, or pests. Even though this technique is still in the research and development stage, it has been applied to the growth of such crops as: potatoes, apples, watermelon, oranges, cucumbers, tomatoes, plums, walnuts, peas, and tobacco. A distinct advantage of this technology is that the fruit does not contain a modified gene. [33]

Controversial Issues

It has been reported that the global production of genetically modified crops will increase at an exponential rate within the next ten years. [34] In a review article published in 2008, it was reported that 840 million people in developing countries were chronically undernourished. The authors also stated that in order to keep pace with the population growth food production must increase by 40%. Thefore, a few of the advantages of producing genetically modified crops include: addressing the problem of world hunger by increasing crop yields, producing crops resistant to disease, pests and drought, improving the nutritional quality of crops, and enhancing the conservation of soil, water and energy. Conversely, they pointed out that the disdvantages include: potential public health issues involved with the consumption of genetically modified crops, adverse environmental effects, as well as ethical considerations. [35]

Even though such notable organizations as the American Association for the Advancement of Science, the American Medical Association, the National Academies of Sciences and the Royal Society of Medicine have all agreed that genetically modified crops are safe, there are still critics who are concerned about potential health risks. [36] In the United States the production of genetically modified crops are under the regulatory authority of the Food and Drug Administration, the Environmental Protection Agency, the National Institutes of Health, and the United States Department of Agriculture. All of these governmental agenies monitor the safety of genetically modified plants. [37] In response to a number of questions received by the World Health Organiztion, they published a pamplet addressing those concerns. Of the twenty questions, the following two involved human health and they are: 1. "How are the potential risks to human health determined?" and 2. "What are the main issues of concern for human health?". The answer to question 1 involved assessing the toxicity, studying the allergenicity, determining the stability of the gene, examining the nutritional effects, and assessing any unintended effects. The answer to question 2 again focused on allergenicity, gene transfer, and outcrossing. [38] Two areas that the students will focus on include human health issues and environmental concerns.

Strategies

In an ongoing effort to improve student literacy, the School District of Philadelphia adopted an initiative based on six instructional strategies. [39] Among the strategies that will be used throughout this unit are: previewing content specific vocabulary, summarizing material by structured note taking, reciprocal teaching, and writing short compositions on what has been read.

Parts of the unit will also necessitate the use of cooperative learning strategies. Classroom management, however, is essential for a successful cooperative learning environment. This can be accomplished through: cooperative management, the will to cooperate, and the skill to cooperate. It is imperative that students understand the guidelines for acceptable classroom behavior. The will to cooperate is developed over time and is based on positive social interactions and pride within the group. The skill to cooperate is based on the ability of the students to assume specific roles within the group, listen to, and work with each other.

The fundamental behavioral skills that are associated with cooperative learning include: simultaneous interaction, positive interdependence, and individual accountability. Within a cooperative learning environment, the students are encouraged to interact with members within their group. This freedom is usually not permissible within a traditional classroom setting. Positive interdependence is gained from the achievement of individual students within the group and from the entire group as a whole. Individual accountability can be addressed by employing a variety of assessments.

Classroom management is always a major concern especially with freshman students. To a large degree, effective classroom management depends upon the structure of the lesson and its delivery. Not only does it involve the arrangement of the students within the group, but it is also dependent upon the manner in which individual lessons are designed and presented. These structures, designs, or activities are meant to improve such areas as team building, information sharing, thinking skills, communication skills, and content literacy. A brief list of classroom structures and lesson designs include: brainstorming, jigsaw, numbered heads together, rally table, round robin, roundtable, student teams achievement division (STAD), team projects, and think pair share. A detailed review of each can be found in *Cooperative Learning*. [40]

By improving their note taking skills, students should be able to utilize, practice and/or engage in summarizing content specific material. To achieve that objective, the highly successful technique of note taking that was developed by Walter Pauk will be employed. The Cornell Method, as it is referred to, involves writing a key word, phrase, or concept on the left hand side of a sheet of paper. On the right hand side of the paper, relevant material is then written in short sentences or phrases. Finally, at the bottom of the page, the material listed is then summarized into a short paragraph. This widely used method enables students to improve their skills in summarizing material presented in both lecture and written form. [41]

In order to address and improve reading comprehension skills, students will participate in reciprocal teaching techniques. This is another cooperative learning strategy which is designed to encompass the following four skills: summarizing, questioning, clarifying, and predicting. Each student within the group will be responsible for reading a specific section within their textbook and/or assigned reading material, summarizing that material, and reporting out to the rest of the group. This pedagogical strategy has been reported to be successful in both small groups as well as in large classroom settings. [42]

Classroom Activities

The activities used in this curriculum unit will incorporate the use of a McGraw-Hill computer simulated virtual lab in addition to three case studies obtained from the National Center for Case Study Teaching in Science. These activities have been carefully chosen to achieve the primary goal of improving reading comprehension skills. The National Center for Case Study Teaching in Science has stated the following: "In our 20 years of working with this method, we have found it to be a powerful pedagogical technique for teaching science. Cases can be used not only to teach scientific concepts and content, but also process skills and critical thinking." [43]

Activity 1

This is a McGraw-Hill computer simulated virtual lab obtained from http:www.mhhe.com/genbio/virtual_labs_2K8/labs/BL_01/index.html and is entitled "Dependent and Independent Variables". The students will examine the growth of four different varieties of corn plants in the presence of the European Corn Borer. Two of the corn plants are grown from different wild type seeds, whereas the other two plants represent the growth from different varieties of BT transgenic seeds. These seeds contain the gene for a toxin produced by the bacterium *Bacillus thuringiensis*. The students will complete the worksheet and post-lab questions that accompany the lab. One period of fifty-seven minutes will be allocated for this activity.

Activity 2

This activity, "*Frankenfoods? The Debate Over Genetically Modified Crops*" was developed in 2001 by Bill Rhodes, Maha M. Alkhazindar, and Nancy Schiller. It was obtained from the National Center for Case Study Teaching in Science at http://sciencecases.lib.buffalo.edu/cs/files/3-gmfoods.pdf. This activity involves arranging the class into collaborative learning groups composed of three or four students. After reading the case study which deals with the vandalism of a university greenhouse housing genetically modified plants, the students will examine the benefits and risks of biotechnology. Each group will report their answers to the worksheet that accompanies this case study.

Activity 3

"*Torn at the Genes: One Family's Debate Over Genetically Modified Plants*" is a case study developed by Jennifer Nelson and Clyde Freeman Herreid in 2000 and available through the National Center for Case Study Teaching in Science at http://sciencecases.lib.buffalo.edu/cs/files/torn_genes.pdf. This activity will span approximately three periods. It involves a heated debate among family members at the dinner table. Students within individual cooperative learning groups will answer the questions supplied at the end of the case study. Each group will report their answers which will be the basis for a whole class discussion.

Activity 4

Wayne Shew and Mary Celeste Reese developed this case study in 2007. "*Do You Really Know What You're Eating? A Case Study on Genetically Modified Foods*" was obtained from the National Center for Case Study Teaching in Science at http://sciencecases.lib.buffalo.edu/files/gmo_safety.pdf. Initially, the students will read an article dealing with the possible allergic reactions to eating tacos prepared from genetically modified corn. Each cooperative learning group will be required to prepare a ten minute power point presentation on any one of fifteen options that involves technical aspects of genetic engineering and biotechnology.

Annotated Bibliography

Arms, Karen. *Holt environmental science*. Orlando: Holt, Rinehart and Winston, 2006.

This is the School District of Philadelphia's approved textbook for high school environmental science courses.

Miller, G. Tyler. *Living in the environment: principles, connections, and solutions*. 13th ed. Australia: Thomson-Brooks/Cole, 2004.

This is an excellent environmental science resource textbook.

Raven, Peter H., and George B. Johnson. "Gene Technology." In *Biology*. 6th ed. Boston: McGraw-Hill, 2002. 389-418.

This book has an excellent chapter on gene technology and agricultural applications of genetic engineering.

Withgott, Jay, and Scott R. Brennan. *Environment: the science behind the stories*. 4. ed., internat. ed. San Francisco [u.a.: Pearson/Benjamin Cummings, 2011.

This is an excellent environmental science resource with a thorough chapter on the agricultural applications of genetic engineering.

Wright, Richard T., and Dorothy F. Boorse. *Environmental Science: Toward A Sustainable Future*. 12 ed. Boston: Pearson, 2014.

This is a nice resource for the production of genetically modified crops.

Appendix/Standards

This curriculum unit will be aligned to the Pennsylvania academic standards for science and technology The specific standards that will be addressed during the course of this curriculum unit were taken directly from the *Pennsylvania Teacher's Desk Reference and Critical Thinking Guide* and include:

3.8.12 Science, Technology and Human Endeavors

A. Synthesize and evaluate the interactions and constraints of science and

technology on society.

- Evaluate technological developments that have changed the way humans do work and discuss their impacts (e.g. genetically engineered crops).

B. Apply the use of ingenuity and technological resources to solve specific

societal needs and improve the quality of life.

- Apply appropriate tools, materials and processes to physical, informational or biotechnological systems to identify and recommend solutions to international problems.

C. Evaluate the consequences and impacts of scientific and technological

solutions.

- Analyze and communicate the positive or negative impacts that a recent technological invention had on society.

4.4.12 Agriculture and Society

A. Analyze the management practices in the agriculture business.

- Identify the diversity in crop production and analyze the advantages and disadvantages of such diversity.

- Research and analyze environmental practices related to agricultural systems.

B. Describe how agricultural science has influenced biotechnology.

- Investigate how bio-engineered crops may influence the food supply.

C. Analyze and research the social, political and economic factors that affect agricutural systems.

- Analyze the costs and benefits associated with agricultural practices and how they affect economic and human needs.

- Analyze the costs and benefits of agriculture research practices in society.

D. Analyze research and development activities as they relate to agriculture.

- Analyze the role of research, development and technology as it relates to the food and fiber system.

4.6.12 Ecosystems and Their Interactions

C. Analyze how human action and natural changes affect the balance within an

ecosystem.

- Analyze effects of human action on an ecosystem.

4.8.12 Humans and the Envioronment

A. Explain how technology has influenced the sustainability of natural resources over time.

- Describe how technology has changed the use of natural resources by business and industry.

B. Analyze technology's role on natural resource sustainability.

- Explain how technology has impacted the efficiency of the use of natural resources.

D. Analyze the international implications of environmental occurrences.

- Analyze environmental issues and their international implications.

Notes

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[1] "Standards - Common Core." SAS - Pennsylvania Department of Education Standards Aligned System. http://www.pdesas.org/standard/commoncore (accessed July 13, 2013).

The Pennsylvania common core standards for reading in science and technology are listed for grades six to twelve.

[2] "Teachers' Implementation Tool Kit: Supporting Common Core Standards Outcomes." The School District of Philadelphia Office of Curriculum, Instruction, and Assessment. http://westphiladelphiahs.wikispaces.com/file/view/COMMON+CORE+TOOLKIT.pdf (accessed July 13, 2013).

The booklet is intended to assist teachers in improving student literacy and mathematics.

[3] Minkoff, Eli C., and Pamela J. Baker. "Genes, Chromosomes, and DNA." In *Biology today: an issues approach*. 3rd ed. New York: Garland Pub., 2004. 34-39.

The authors clearly discuss Gregor Mendel's work and contributions to genetics.

[4] Ibid. 54-56.

Alfred Hershey and Martha Chase's experiment and contributions are given in detail.

[5] Hershey, A. D.. "Independent Functions Of Viral Protein And Nucleic Acid In Growth Of Bacteriophage." *The Journal of General Physiology* 36, no. 1 (1952): 39-56.

This was Hershey and Chase's original article demonstrating the hereditary nature of DNA.

[6] Alberts, Bruce, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter. "DNA and Chromosomes." In *Molecular biology of the cell*. 4th ed. New York: Garland Science, 2002. 191-197.

The structure of DNA is explained quite well.

[7] Mathews, Christopher K., and K. E. Holde. "Nucleic Acids." In *Biochemistry*. Redwood City, Calif.: Benjamin/Cummings Pub. Co., 1990. 91-120.

This is an extremely detailed account of the chemical structure of nucleic acids.

[8] Minkoff, Eli C., and Pamela J. Baker. "Genes, Chromosomes, and DNA." In *Biology today: an issues approach*. 3rd ed. New York: Garland Pub., 2004. 56-59.

This section gives is a very simplistic description of the structure of DNA.

[9] Watson, J. D., and F. H. C. Crick. "Molecular Structure Of Nucleic Acids: A Structure For Deoxyribose Nucleic Acid." *Nature* 171, no. 4356 (1953): 737-738.

This was Watson and Crick's original paper delineating the structure of DNA.

[10] Crick, Francis. "Central Dogma Of Molecular Biology." *Nature* 227, no. 5258 (1970): 561-563.

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