What are GMOs?

Genetically modified organisms (GMOs) refer broadly to organisms that are produced when selected individual genes are transferred from a given donor organism into another target organism, typically conferring desired properties to the new organism. GMOs can include plants, animals, and enzymes. Some GMOs have been approved by regulatory agencies for commercial production and consumption, while others are currently undergoing regulatory evaluation. Still other GMOs are in experimental stages and confined to scientific laboratory research.

GM foods are derived from genetically modified organisms (GMOs), specifically plants and animals of agricultural importance. GMOs are defined as organisms whose genomes have been altered in ways that do not occur naturally. Although the definition of GMOs includes organisms that have been genetically modified by selective breeding, the most commonly used definition refers to organisms modified through genetic engineering or recombinant DNA technologies. Genetic engineering allows one or more genes to be cloned and transferred from one organism to another—either between individuals of the same species or between those of unrelated species. It also allows an organism's endogenous genes to be altered in ways that lead to enhanced or reduced expression levels. When genes are transferred between unrelated species, the resulting organism is called **transgenic.**

The most widely used GM insect-resistant crops are the **Bt crops**. *Bacillus thuringiensis* (Bt) is group of soild welling bacterial strains that produce crystal (Cry) proteins that are toxic to certain species of insects. These Cry proteins are encoded by the bacterial cry genes and form crystal structures during sporulation. The Cry proteins are toxic to Lepidoptera (moths and butterflies), Diptera (mosquitoes and flies), Coleoptera (beetles), and Hymenoptera (wasps and ants). Insects must ingest the bacterial spores or Cry proteins in order for the toxins to act. Within the high pH of the insect gut, the crystals dissolve and are cleaved by insect protease enzymes. The Cry proteins bind to receptors on the gut wall, leading to breakdown of the gut membranes and death of the insect. Each insect species has specific types of gut receptors that will match only a few types of Bt Cry toxins. As there are more than 200 different Cry proteins, it is possible to select a Bt strain that will be specific to one pest type.

Importantly, the production of transgenic animals and plants that contain genetic elements from foreign sources and possess novel traits and characteristics is also based on the techniques outlined above. As all these approaches result in the creation of genetically modified organisms (GMOs) that can be potentially harmful to the environment and human health, the part of biotechnology that deals with GMOs is strictly regulated by biosafety laws and guidelines. The main thrust of this resource book is on the development and enforcement of such regulatory frameworks at domestic and international levels.

Genetic Modification of Bacteria Bacteria —

The first organisms to be genetically engineered — are used for replicating and altering genes that are subsequently introduced into plants or animals. Bacterial systems lend themselves to genetic manipulation in part because of their rapid reproduction rates. It is easy to produce a genetically identical population — a clone of bacteria — all containing the gene of interest in a short period. The cells can then be lysed and DNA can be isolated in short order. Bacteria are routinely used to produce non-bacterial proteins. An example is the production of purified proteins for vaccine use. Such proteins can be safer and as effective as vaccines that contain killed or attenuated (weakened) pathogens. Genetic engineering can also produce extensive changes in the bacterium's metabolism. For example, bacteria can be provided with several genes encoding enzymes that allow the production of fuel alcohol from wood.

Genetic Modification of Plants

New traits introduced to crop plants by genetic engineering have the potential to increase crop yields, improve agricultural practices, or add nutritional quality to products. For example, transgenic crop plants capable of degrading weed killers allow farmers to spray weeds without affecting yield. Use of herbicide-tolerant crops may also allow farmers to move away from preemergent herbicides and reduce tillage, thereby decreasing soil erosion and water loss. Transgenic plants that express insecticidal toxins resist attacks from insects. Crops engineered to resist insects are an alternative to sprays, which may not reach all parts of the plant. They are also cost effective, reducing the use of synthetic insecticides. Genetic engineering has also been used to increase the nutritional value of food; "golden rice" is engineered to produce beta-carotene, for example. Edible vaccines, present in the plants we eat, may be on the horizon.

Genetic Modification of Animals

Dolly the lamb stole the headlines as the first example of livestock cloned from DNA of an adult animal. But the real breakthrough came with Polly, the first transgenic lamb. Born the year after Dolly, Polly was given a human gene that encodes blood-clotting factor IX, the protein missing in people with one form of hemophilia. Harvesting such proteins from transgenic livestock is one goal of this research. The road to Polly and subsequent transgenic animals began with research using genetically altered mice. Along the way, technologies for cloning animals, modifying DNA, and targeting expression of proteins to specific tissues were developed. Someday, human gene therapy — supplying genes to patients with missing or altered proteins — may become common practice. However, significant challenges remain. Moreover, risks and ethical concerns must be addressed.

Techniques Used for Generating Transgenic Plants

One approach is to use a "gene gun," (Fig. 3) which fires plastic bullets filled with DNA-coated metallic pellets. An explosive blast or burst of gas propels the bullet toward a stop plate. The DNA-coated pellets are directed through an aperture in the stop plate, and then penetrate the walls and membranes of their cellular targets. Some projectiles penetrate the nuclei of cells, where occasionally the introduced DNA integrates into the DNA of the plant genome. Transformed cells can then be cloned in culture.

Researchers working with rice often use the soil bacterium Agrobacterium tumefaciens. This bacterium, the cause of crown gall disease in many fruit plants, is well known for its ability to infect plants with a tumor-inducing (Ti) plasmid. A section of the Ti plasmid, called T-DNA, integrates into chromosomes of the plant. Recombinant DNA can be added to the T-DNA, the gall-inducing genes removed, and infection by the bacteria — containing the recombinant plasmid — will provide for transfer of novel genes to plant embryos.

Advantage:

1. GMO crops can be tailored to provide better health benefits.

GMO foods can be modified so that they provide a complete nutritional profile. Multiple vitamins and minerals can be built into the crops as they grown by adjusting the genetic profile of the plant, making it possible for people to get what they need with fewer foods and lower costs. That makes it possible to provide more people who are living in poverty with the food resources they need to maintain their health.

2. There is the possibility of an increased shelf life.

GMO crops can be engineered to last longer once harvested, which makes it possible to extend the distribution life of the food product. That makes it possible to use the existing infrastructure for food distribution to send healthy foods further around the world. That means locations which are experiencing food deserts or shortages can still receive affordable foods that can benefit the general population.

3. It takes less land to grow more food.

GMO crops can be engineered to produce higher yields from the same croplands. In some instances, the crop yields can potentially double when the transition from traditional crops to GMO crops is completed by local farmers. That makes it possible to meet the food demands that future generations are going to face. By 2050, upwards of 10 billion people are expected to be living on our planet. Oxfam currently estimates that global food production is enough to feed about 8 billion people.

4. Genetically modified crops can conserve energy, soil, and water resources.

That allows our food distribution networks to make less of an impact on the environment. Food can be grown in areas that receive very little rainfall and have zero irrigation with proper genetic modifications. Crops can be grown on fields with little soil. Because the crops have an increased resistance to disease, weeds, and pests, there is greater consistency in the yields that can be produced. That makes it easier to budget food resources for a larger population base.

5. Simple changes to certain crops can have a major impact.

The United Nations, through their Food and Agriculture Organization, suggests that the easiest way to decrease vitamin A deficiencies is to genetically modify rice to have higher levels of this nutrient. Because half of the world's population consumes rice on a daily basis, the high rates of this vitamin deficiency could be resolved with this one simple change. Bananas in Uganda are being looked at for this vitamin enhancement as well, while soybeans provide higher levels of Omega-3s without trans-fats.

6. Fewer harmful agents need to be applied to crops.

GMO crops are more resistant to pests, weeds, and other threats. That means farmers have less of a need to apply pesticides or herbicides to their crops, which saves them money and potentially increases the health benefits of the food being grown. Farmers can also make more money from their existing croplands because there are greater yields with GMO crops. Even the sustainability benefits, such as drought-resistance, can maintain yields so that fewer subsidies are required.

7. It can save core crops from extinction.

Many of the foods we eat today are products of a single initial resource. Every naval orange, for example, is essentially a clone of one original tree that was grafted to created additional trees. That lack of genetic variation puts the crop at-risk should a virus or bacteria be able to attack the basic genome of the crop. We've already seen that happen with the Hawaiian Rainbow Papaya and genetic engineering helped to save the industry. Something similar could happen to navel oranges or any other crop.

8. Farmers can use better ground-care methods.

Because GMO crops have a greater overall tolerance, no-till farming methods become a possibility. Even if tilling is required, less may be necessary to successfully plant a crop. That means less irrigation may be necessary. Less nutrient runoff may be experienced. Soil erosion can be reduced. At the same time, the safety and nutritional value of the crops are not placed at-risk.

9. Future GMOs could eliminate food allergies or intolerance issues.

Current genetic engineering research is focused on removing the allergen triggers that are present in common foods, like peanuts. Intolerance issues that are caused by glutencontaining foods or other triggers are also being examined. The future of food science in the world of GMOs could make it possible for people with food allergies or intolerance issues be able to safely eat foods they love in the future.

10. GMO crops use less water

From 1980 to 2011, the amount of irrigation water required for fields planted with corn decreased by 53%. For cotton fields the amount of irrigation water decreased by 75%. Soybeans, rice, and potatoes all saw decreases of at least 38%. Even wheat fields saw a 12% decrease in irrigation water consumption when planted with GMO crops compared to traditional crops.

11. There may be a positive environmental impact with GMO crops.

In general terms, GMO crops require fewer in-field operations and applications to maintain the quality of the yield. Because of this, fewer passes over the field are required. That reduces the amount of carbon dioxide and other greenhouse gases that are created through fossil fuel combustion with tractors, combines, and other farming equipment. Carbon dioxide is also stored in the soil, so fewer passes means less of a release occurs there as well.

12. GMO foods must meet the same standards as traditional foods.

For GMO food products to be sold in the United States, they must meet the same quality and safety standards as any other food product. When compared to organic foods, Stanford University has even found that there are no additional health risks when eating GMO foods or organic foods. Although there are food allergy concerns, especially in children, any food at any time has the potential of creating an allergy. From a pure nutritional standpoint, GMO foods are equal or greater than what is found at the average grocery store.

13. GMOs can even safe beneficial insects.

When Bt proteins are used in genetic engineering, it targets a specific group of insect pests that are dangerous to that specific crop. Other beneficial insects that would be killed when spraying a general pesticide are saved. Those included proteins have a minimal effect on them. Although there are stories of shepherds letting loose sheep into Bt fields and losing thousands of head of livestock because of it, there are often more positives than negatives to find here.

Disadvantage:

1. **In the US, the FDA does not require GMO labeling.**

GMO ingredients can be placed into food products and US shoppers wouldn't even know it. There are currently no national-level labeling requirements for foods that have GMO ingredients. Some states have looked at creating labeling laws to require

GMO information, but for the most part, only non-GMO foods tend to be labelled right now. The Non-GMO Project reports that 64 countries, including the entirety of the European Union, Japan, and Australia all require labeling.

2.Most core foods have some level of genetic modification.
Commercialized crops include cotton, corn, and soybeans. More than 90% of these crops being grown today have some level of genetic modification. Even sugar beets, grown at commercial levels, are more than 90% GMO. Any products that are derived from these core foods, such as corn syrup or soybean oil, still contain the genetic changes from the core ingredient used to make the item.

3.There may be an increased risk of allergies or food intolerance.
Animal testing may be highly controversial, but it should be noted that GMO foods studied in animals have found organ impacts in virtually every circumstance. In humans, there may be an increased trend of food allergies and digestive intolerance because of genetic modification. When plants produce pesticides inside of the plant to kill insects, by basic definition, that plant is toxic.

4. GMO crops can contaminate other fields.

The crops may be genetically modified, but they still grow the same way as any other crop. That means pollination is required for the crop to produce the "fruit" that is being grown. Bees do much of the pollination work, which means they are exposed to the genetic changes of the plant. Seeds are produced by these GMO crops as well in many instances, which can be spread to other fields and contaminate them. If cross-pollination occurs, there is no predictable outcome for both fields, though soybeans are an exception since they don't cross-pollinate.

5. Animal proteins could be affected by GMO crops.

The vast majority of the core crops in the US that are grown are GMO crops. These crops are then fed to livestock, aquaculture, and apiculture, which impacts groceries that are based on animal proteins. GMO ingredients can be found in milk, seafood, eggs, and animal muscle tissues. Even honey can have GMO ingredients when bees are pollinating genetically modified crops to produce it.

6. Many GMO crops are trademarked, patented, and legally protected.

Farmers that grow GMO crops may be required to sign an agreement to exclusively grow a specific product. They may be asked to take steps that protect the crops being grown from contamination. Farmers that don't take these steps could be taken to court because of breeching that contract. Some companies have even sued farmers who have patented crops growing in their fields because of natural pollination or distribution patterns, despite the fact that no seeds were ever planted by them.

7. It encourages the use of additional herbicides.

More than 80% of GMO crops grown around the world are created to be tolerant to herbicides. Farmers have increased the number of toxic herbicides because of this by more than 1500% since the first GMO crops were introduced. One of those most common herbicides being used, glyphosate, has been listed by the World Health Organization since 2015 as being a probable carcinogenic.

8. GMOs create super weeds.

If nature knows how to do one thing well, it is to adapt. As crops have grown more resistant to weeds, the weeds have grown stronger and more resilient to the chemicals applied to them that try to kill them. Because of this, some farmers have resorted to using ingredients such as 2, 4-D, which is one of the primary ingredients found in Agent Orange. The US Veteran's Administration has a long list of presumptive diseases associated with Agent Orange exposure, with many of them being cancers.

9. GMOs create super bugs.

As pesticides are applied to insects that provide a threat to crops, a few of them tend to survive the application. Each subsequent generation becomes more resilient to the pesticide. That means either more needs to be applied or a stronger agent needs to be applied. When something stronger is placed on the crops, the cycle of resilience begins again. Although GMO crops reduced pesticide use by over 1 billion pounds from 1996-2010, the threat of resilient super bugs that could destroy entire croplands without being affected by a pesticide could reduce food supplies instead of increasing them.

10. There are concerns that GMO foods may help to create antibiotic resistance.

One of the ways that crops are modified to be more resilient to disease is to artificially place antibiotic genes within the DNA of the crops. Because there is evidence to suggest that continuing exposure to an antibiotic can lead to disease resistance, the GMO efforts to create a safer food supply could be a contributing factor to the "super bacteria," such as MRSA, that are increasing in regularity.

11. Genetic engineering doesn't solve everything

Atrazine is one of the most common herbicides that is applied to US croplands. According to the National Institutes of Health, atrazine resistance has been studied since the early 1970s. There are dozens of weed species that are already resistant to this herbicide, with research studies by Bettini, Shimabukuro, and Anderson showing over three decades that resistance is growing.

The advantages and disadvantages of GMOs is a necessary conversation we must have. At some point, we must figure out how to feed our growing population levels. New farming methods can only produce a limited amount of change. With this technology, we have the potential to maximize our resources. Of course, maximizing those resources while creating health problems for future generations may not be the right answer either. We should be working to prevent resistance instead of encouraging it.

Biosafety Protocol

The *Cartagena Protocol on Biosafety to the Convention on Biological Diversity* is an international treaty governing the movements of living modified organisms (LMOs) resulting from modern biotechnology from one country to another. It was adopted on 29 January 2000 as a supplementary agreement to the Convention on Biological Diversity and entered into force on 11 September 2003.

On 29 January 2000, the Conference of the Parties to the Convention on Biological Diversity adopted a supplementary agreement to the Convention known as the Cartagena Protocol on Biosafety. The Protocol seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern biotechnology. It establishes an advance informed agreement (AIA) procedure for ensuring that countries are provided with the information necessary to make informed decisions before agreeing to the import of such organisms into their territory. The Protocol contains reference to a precautionary approach and reaffirms the precaution language in Principle 15 of the Rio Declaration on Environment and Development. The Protocol also establishes a Biosafety Clearing-House to facilitate the exchange of information on living modified organisms and to assist countries in the implementation of the Protocol.

Timeline of the Cartagena Protocol on Biosafety

1993 ***The Convention on Biological Diversity enters into force on 29 December 1993***

1995	COP2	Second meeting of the Conference of the Parties - Consideration of the need for and modalities of a protocol for the safe transfer, handling and use of living modified organisms. *Jakarta, Indonesia, 6 - 17 November 1995*	Decision II/5
1996	COP3	Third meeting of the Conference of the Parties - Issues related to biosafety. *Buenos Aires, Argentina, 4 - 15 November 1996*	Decision III/20
1996	BSWG1	First meeting of the Open-Ended *Ad Hoc* working Group on Biosafety. *Aarhus, Denmark, 22 - 26 July 1996*	Meeting Documents
1997	BSWG2	Second meeting of the Open-Ended *Ad Hoc* working Group on Biosafety. *Montreal, Canada, 12 - 16 May 1997*	Meeting Documents
1997	BSWG3	Third meeting of the Open-Ended *Ad Hoc* working Group on Biosafety. *Montreal, Canada, 13 - 17 October 1997*	Meeting Documents
1998	BSWG4	Fourth meeting of the Open-Ended *Ad Hoc* working Group on Biosafety. *Montreal, Canada, 5 - 13 February 1998*	Meeting Documents
1998	COP4	Fourth meeting of the Conference of the Parties - Issues related to biosafety. *Bratislava, Slovakia, 4 - 15 May 1998*	Decision IV/3
1998	BSWG5	Fifth meeting of the Open-Ended *Ad Hoc* working Group on Biosafety. *Montreal, Canada, 17 - 28 August 1998*	Meeting Documents
1999	BSWG6	Sixth meeting of the Open-Ended *Ad Hoc* working Group on Biosafety. *Cartagena, Colombia, 14 - 19 February 1999*	Meeting Documents
1999	BSIC1	Informal Consultation on the process to resume the Extraordinary Meeting of COP to adopt a protocol on Biosafety. *Montreal, Canada, 1 July 1999*	Meeting Documents
1999	BSIC2	Second Informal Consultation on the process to resume the Extraordinary Meeting of COP to adopt a protocol on Biosafety. *Vienna, Austria, 15 - 19 September 1999*	Meeting Documents
1999 - 2000	EXCOP1	First Extraordinary Meeting of the Conference of the Parties - Decisions on the continuation of the first extraordinary meeting of the Conference of the Parties to the Convention on Biological Diversity, ***adoption of the***	Decisions EM-I/1-3

		Cartagena Protocol and interim arrangements. *Cartagena, Colombia 22 - 23 February 1999 and Montreal, Canada, 24 - 28 January 2000*	
2000	COP5	***The Cartagena Protocol on Biosafety is opened for signature.*** Fifth meeting of the Conference of the Parties - Work plan of the Intergovernmental Committee for the Cartagena Protocol on Biosafety. *Nairobi, Kenya, 15 - 26 May 2000*	Decision V/1
2000	ICCP1	First meeting of the Intergovernmental Committee for the Cartagena Protocol on Biosafety. *Montpellier, France, 11 - 15 December 2000*	Meeting Documents
2001	ICCP2	Second meeting of the Intergovernmental Committee for the Cartagena Protocol on Biosafety. *Nairobi, Kenya, 1 - 5 October 2001*	Meeting Documents
2002	COP6	Sixth meeting of the Conference of the Parties - Intergovernmental Committee for the Cartagena Protocol on Biosafety. *The Hague, Netherlands, 7 - 19 April 2002*	Decision VI/1
2002	ICCP3	Third meeting of the Intergovernmental Committee for the Cartagena Protocol on Biosafety. *The Hague, The Netherlands, 22 - 26 April 2002*	Meeting Documents
2003	***The Cartagena Protocol on Biosafety enters into force on 11 September 2003***		