Genetically engineered organisms (GEOs), or what many call GMOs (genetically modified organisms), are often in the headlines. Headline splash includes new GE crop types, proposed labeling legislation, and even shocking photos claiming to show animals harmed by consuming GE crop products.

What are these crops, how are they made, and what really are the risks and benefits to them?

Most of our domesticated crops and livestock originated thousands of years ago with wild species that early hunter-gatherers found useful as food. They collected and saved beneficial naturally occurring mutants. Mutants are individuals where the genetic code was copied wrong as cells divide, which happens regularly in all organisms.

Gradually genetic changes from naturally occurring mutations combined with farmers’ selection to create a new crop. That profound change (a genetic modification) that began with domestication continues to intensify as knowledge of genetics and performance measurement improves.

Domesticated crops and livestock are no longer “natural.” Most would never survive in nature without a partnership with farmers to cultivate them.

Science can now identify the genetic material of an organism that causes it to produce a particular product. For example, researchers identified a gene in the bacterium *Bacillus thuringiensis* that produces a toxic product when inside a caterpillar’s gut. They then cut out this gene (called the Bt gene) from the bacteria and inserted it into crops like corn and cotton to create insect resistant versions of these plants. That is how genetically engineered Bt corn and Bt cotton are produced. For each insect, a slightly different variant of the Bt gene from the bacterium is used because those genes differ in how effective they are against different insect species. Corn has a Bt-corn borer gene that is slightly different from the Bt-corn rootworm gene. Both genes are built into commercially available GE corn varieties.

A similar process was used to create GE plants that tolerate being sprayed with herbicides normally toxic to plants. These include the glyphosate (Roundup) resistant gene and the glufosinate (Liberty) resistant gene, both found naturally in soil bacteria. Herbicide resistance from these genes (especially the “Roundup Ready” glyphosate resistance) was built into many GE crops, including soybean, corn, cotton, alfalfa and sugarbeet.

Genetically engineered insect resistant (Bt) and herbicide tolerant (HT) crop varieties, including many with both traits together, are planted on the majority of US soybean, field corn and cotton acres. The USDA chart shows the share of US acres planted to GE varieties of these crops since they were first commercialized in 1996. Clearly they have been widely adopted by farmers.

How does genetic engineering differ from “traditional” plant breeding? “Traditional” plant breeding means the kind of selection and breeding practiced by early farmers and still practiced by plant breeders – cross pollinating to find offspring that are genetically superior. In contrast, the GE crop varieties cultivated commercially today were created by transferring individual genes between organisms that could not naturally cross with each other, like a soybean and a bacterium. For many years, plant breeders made crosses between crops and their wild relatives to transfer genes for traits like pest resistance to the domesticated crops, so this process is not entirely new. However, traditional plant breeders are limited to transferring genes between organisms that are closely enough related to be sexually crossed. A second difference is that with sexual crosses, all the genes in the parents are mixed in the offspring, including desired genes and others. Genetic engineering (GE) introduces only the
desired gene or few genes, and genetic sequences needed for their identification and expression. This is why GE approaches are sometimes described as more precise than traditional breeding. Lastly, the ability to identify and manipulate individual genes has led to the legal right to patent genes, so most, if not all, GE traits are patented and their use is legally constrained.

Both approaches depend on variation or changes in the genetic sequence to create crops that are more useful. Both approaches aim to modify crops to better meet human needs, just as the earliest farmers who domesticated crops did. Finally, it is not new that private companies seek a return on their investments in plant breeding research. With traditional plant breeding, they were able to do that through plant variety protection laws and through marketing hybrid varieties that require annual seed purchases. With genetic engineering, the option of patenting genes provides another avenue for return on investment. Thus, although genetic engineering is a distinct new tool for plant breeding, it shares the same fundamental elements as traditional plant breeding.

What are the risks and benefits of GE crops? From a farmer’s point of view, one of the first questions is whether returns from using a GE variety justify its cost. The answer will vary from farm to farm. Seed of GE varieties is typically more costly because of the “technology fees” for the GE traits. In addition, GE varieties are sold with technology use agreements that prohibit saving seed from those varieties, even for your own on-farm use. Some GE varieties allow reduced labor and production costs, greater flexibility in management and increased convenience for producers. On the other hand, some international markets have limited acceptance of GE varieties. In the future, GE crops whose products have value-added benefits for consumers or processors may be available and thus they will receive price premiums. But these varieties are not yet commercialized. What should be clear is that costs and benefits are very case specific, depending on the individual farm operation, the GE crop and trait being considered and the marketing environment.

Producers and consumers are concerned about environmental impacts of GE crops. Some of these impacts may be positive. For example, from reduced pesticide use or less need for tillage resulting in reduced erosion potential. On the negative side are concerns about potential environmental impacts of pest resistant GE varieties on non-target organisms, “gene escape” from GE crops to their wild and weedy relatives through sexual crosses, and pest evolution to overcome GE resistance. The latter is a risk for any pest control method, including traditionally bred resistance, chemical pesticides, and even some cultural control methods. Evolution of pest resistance to a control measure happens most readily when a single control approach is used repeatedly and over a large acreage. That is exactly what is happening with glyphosate resistant crops, and farmers are beginning to see weeds that are less well controlled. The same problem may be occurring with corn carrying the Bt-corn rootworm trait. Both are very popular and provide very good pest control. Their effectiveness has contributed to overuse that favors evolution towards more resistance by the pests. Rotating or alternating pest control methods is a principle learned long ago and promoted through integrated pest management programs. It seems we need to re-learn it with respect to GE pest resistance tools!

Are GE crop varieties safe as food or feed, and can GE approaches introduce allergens into food? Food safety testing of GE crops in the US is based on a principal called “substantial equivalence.” Nutritional components are compared to see if a new GE variety falls within the range of normal variation for non-GE varieties of the crop. If so, the GE variety is considered substantially equivalent to non-GE varieties and food safety testing is voluntary. This approach is not reassuring to concerned consumers. The problem is that toxicological safety testing would reveal natural toxicants in the non-GE foods that we have eaten and accepted as safe for decades. Toxicology tests offer a very high dose of a food or additive to a laboratory organism over a very short period of time, which is not how we consume foods in a normal diet. Consequently, the US stipulates that a new GE variety should be as safe as traditional varieties. Required safety testing is focused on cases where a product is not “substantially equivalent” to its non-GE counterpart.

Some concerned consumers note that all US GE varieties commercialized have been declared “substantially equivalent.” Consumers worry that this label avoids careful food safety testing. Companies marketing GE varieties provide assurance that extensive testing is done, but often results are confidential. Again, not reassuring. The good news is that a body of over 100 independently-funded studies has not revealed evidence of any food or feed safety concerns with currently commercialized GE crops. Those few studies that have purported to show problems from feeding GE crops have been very widely discredited by experienced scientists for their poor design, inappropriate analysis and other scientific problems.

Concern about novel and unanticipated allergens is also important for consumers. The example most often cited is one that never came close to commercialization: an effort to engineer a Brazil nut gene into soybean to improve its nutritional value. The company realized early on that it would trigger reactions in people with allergies to nuts and immediately halted development. That is reassuring, but does not address concerns that genes from organisms we don’t normally consume as food might have allergenic potential. Testing for allergens has relied on scientific understanding of the general nature of allergenic compounds, and on evaluating how fast the new products produced by GE varieties break down in human digestive enzymes. Introduced genes that produce products like known allergens are extensively tested. Any products that break down more slowly than others when exposed to digestive enzymes, extending time to elict a reaction, are extensively tested. This approach has not proven reassuring, but it is not clear that a better approach exists.

Some people are concerned that GE crops contribute to consolidation, globalization and industrialization in agriculture. The ability to patent genes appears to vest control to large private sector corporations. Some people oppose GE technology based on ethical or religious beliefs. These concerns cannot be answered by scientific studies. They will have to be addressed through policy making and regulation in the form of societal value judgments.

What’s the bottom line? GE is a new and different tool for crop improvement. Varieties need to be monitored for their effectiveness, safety and environmental impacts, just like any other new technology. GEOs, just like any other technology, are not a silver bullet. They must be used wisely.