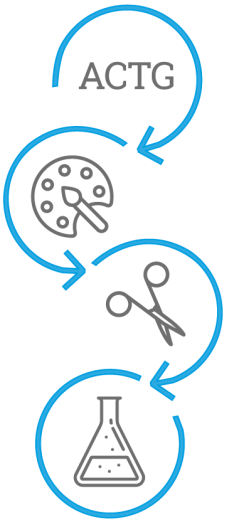

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Simple explanations
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Genetically Modified Organisms (GMOs)

What it is:

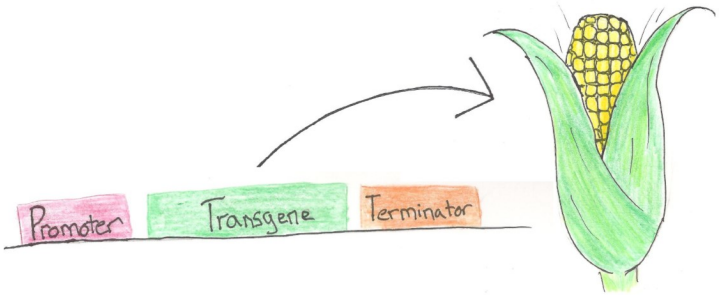
Giving organisms the traits we desire

The crops that farmers grow today look very different from the wild counterparts from which they are descended. Corn, for example, is descended from a wild grass. Cabbage, broccoli, cauliflower, kale, brussels sprouts, collard greens, savoy, and kohlrabi are all descended from a single species of wild cabbage. Like all domesticated organisms, they have been changed over time through traditional breeding techniques, selection, and hybridization. These techniques have changed the genetic makeup of these crops dramatically from their wild ancestors, and in this way, farmers have been genetically modifying crops for thousands of years. Advances in genetic science over the last 30 years, however, have allowed scientists to take new approaches to altering the genetic makeup of the plants, and sometimes animals, we raise for food or other agricultural uses. Scientists can now choose the very specific sequences of DNA they are interested in and place them in unrelated organisms where they did not previously occur.

The most common modifications found in agriculture today are the introduction of a gene that provides resistance to glyphosate, the main ingredient in the popular herbicide Roundup, and a gene that produces a protein found in the bacteria *Bacillus thuringiensis* (Bt) that kills certain insects. These modifications are found widely in crops such as corn, soy, and cotton. If you've eaten processed foods containing soy or corn recently, chances are they contained genetically modified (GM) ingredients. The traits that GM crops offer make them extremely attractive to farmers, and their use has increased productivity of farms and even farmer profits. As the human population continues to grow, many people think that GM foods are one piece of the puzzle to keeping up with increased food demands.

How it works:

Moving genes between species



To make most GMOs, a scientist first identifies a trait that she wants a particular organism to have. This is usually in the area of disease or pest resistance, drought tolerance, herbicide resistance, or even increased nutrition. They then look for a gene that conveys that trait, usually from a different organism. Because the genetic code is universal, scientists can copy the sequence from the original organism and create what is known as an expression cassette. The cassette is a sequence of DNA that usually consists of a promoter region (a sequence that directs the cell to make mRNA), an open reading frame (the sequence of DNA that will be turned into mRNA and codes for protein), and a termination sequence that marks the end of transcription. This cassette is then inserted into the genome of the organism of interest. This final step, inserting the cassette into the genome is the most difficult, time consuming, and expensive step of the process. And because organisms that are modified in this way require several rounds of regulatory approval, it can take several years and millions of dollars from the time that scientists begin working on a new GMO and when it is finally released for commercial use.

New genetic techniques, such as CRISPR/Cas9, are likely to bring dramatic change to how GMOs are produced in the future. Instead of inserting whole new sequences of DNA, scientists can now make small edits directly to existing genes within the genome. This more direct technique may simplify the process of creating new GMOs and actually make the line between traditionally bred crops and GM crops harder to distinguish and identify.

The controversy

Just food or "Frankenfood"?

The vast scientific consensus is that GM foods are completely safe to consume, that GM crops pose no inherent risk to grow, and that GM foods have no inherent nutritional differences. Still, GM foods continue to provoke people's fears, especially around issues of human health. But GMO foods usually contain just one or two additional proteins among the tens of thousands of other proteins the organism produces naturally. This is an extremely small change to the overall composition of the food. It is possible that the added proteins could act as allergens, but this has never been documented and is tested for prior to the release of new GM crops. While new crops could theoretically be developed that do possess a health risk, in the U.S., three government agencies, the FDA, the USDA, and the EPA, must all approve the use of a new GM crop before it can be grown and sold commercially. Regulatory approval can be more difficult in many other countries.

How GM crops affect the environment compared to conventional crops is a little less certain. Some people are concerned that use of herbicide resistant crops results in the overuse of herbicides by farmers. On the other hand, herbicides are used widely on non-GMO crops as well, and glyphosate, the herbicide most widely used on GMOs, tends to be less toxic than many other herbicides in use. And while some environmentalists are concerned about the effect Bt crops will have on natural insect populations, non-GM crops are regularly sprayed with more toxic pesticides. There is a related concern that pests will evolve resistance to Bt crops and that resistance to glyphosate will be selected for in weeds, or that the transgenes could be passed to weeds through rare hybridization events. How the so called "superweeds" that develop would affect the environment is unclear, but it could create problems for farmers of the future.

Some of the more difficult questions surrounding GMOs are even more nuanced and sometimes get much less attention. Genetic diversity in today's agriculture, environmental impacts of large scale farming techniques, corporate vs. farmers' interests, and sustainability of modern agriculture practices are all complex issues that GMOs now play a role in. These questions are not necessarily unique to GM crops, but their widespread use means that GMOs layer new levels of complexity on already difficult problems.

Some people argue that we should at least label genetically modified foods because it is the consumers' right to be informed about what they are buying. Others argue that as the overwhelming scientific consensus is that GM foods are completely safe to consume, labeling foods will give a false impression otherwise and will unnecessarily stoke public fears. In trying to sort it all out, it can be important to remember that GMOs simply represent a new technology; it is up to people to choose how that technology is used.

Learn more:

- "FAQs on Genetically Modified Foods." World Health Organization. Link
- "GMOs." *Wikipedia*. Link.
- Regalado, Anthony "These are not your Father's GMOs." *MIT Technology Review* . Link.

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Questions:

Review:

1. What is meant by the statement that "farmers have been genetically engineering crops for thousands of years"?
2. What are some traits that would be advantageous to introduce to crops?
3. What are the normal components of a transgenic cassette?
4. Are there benefits to eating non-GM foods?
5. If herbicide resistant crops lead to more herbicide use, and Bt crops produce natural pesticides, why is it not clear that this is bad for the environment?

Critical Thinking:

1. In what ways is creating genetically modified crops similar to more traditional methods of breeding crops? How is it different?
2. Why would growing glyphosate resistant crops lead to glyphosate resistant weeds?

Discussion:

1. Should food labels contain information as to whether the ingredients are genetically modified? Is it the right of consumers to be able to choose whether or not they consume GMOs? Does requiring labels lead to consumers think that GMOs are somehow unsafe or undesirable? Who should make such decisions?

Answer key:

Available to teachers upon request: dnadots@minipcr.com