GLP tackles one of the most frequently asked biotech questions: What are GMOs?

"The term genetically modified organisms (GMOs) is a useless and imprecise category used to pigeonhole products. It is theoretically and practically impossible to precisely specify a supposed common denominator for all these products."

—Giovanni Tagliabue, Italian life sciences philosopher, Nature

"GMOs are produced by human actions that are clearly defined, both scientifically and legally. Hence, although humans have been breeding plants for millennia, they have not been directly modifying genetic material until very recently."

—Janet Carter, soil scientist and Greenpeace consultant

Crop biotechnology has been used to enhance food production since the first GMO product, the Flavr Savr tomato, was approved for human consumption in 1994—only to flop because, while extra firm, it was expensive and not as flavorful as other tomato varieties. But the

technology has improved since then. With the help of genetic engineering, scientists have bred a variety of GMO plants that resist pests, makes it easier for farmers to control weeds, enhances nutrition, or survives changing climates. Although not specifically designed to boost yields, many new crop varieties do just that, and have led to significant reductions in the volume of highly toxic chemicals used in agriculture.
Despite a promising track record, the GMO revolution has faced strong headwinds. Many environmental advocacy groups, from Greenpeace to Friends of the Earth to pro-organic groups such as the Organic Consumers Association, have made a public case, challenged for the most part by mainstream science, that crop engineering helps farmers and multinational agro-chemical businesses at the expense of consumers. Unsurprisingly, consumer confusion abounds. A recent survey by a global team of social scientists found that 69% of Americans "aren't confident they understand what genetically modified organisms are," and a strong majority of respondents (74%) said they wanted to know more about the impact of genetic engineering on human health. Consumers also say they would be more open to genetically engineered crops and food if they understood the science behind them.
Consumer curiosity about crop biotech is poised to grow as the gene-editing revolution equips farmers and scientists with novel tools, such as CRISPR-Cas9. That means there are more questions and controversies ahead, but also more opportunities to engage on critical issues, such as how we can make farming more sustainable as we face climate change.

That's where the Genetic Literacy Project comes in. To help the public develop a well-rounded understanding of key scientific, ethical and regulatory issues, the GLP has authored a series of nearly 50 background briefings addressing the most frequently asked questions about the use of GMOs and gene editing in agriculture, from apples to animals. The articles are organized into six categories–Fundamentals; Farming & Food; Health & Safety; Sustainability; Labeling; and Regulation–and provide a science-grounded introduction to crop biotechnology. A few times each month, we will be offering analysis of controversial agricultural innovations through these FAQs, as we explore the rapidly advancing GMO and gene-editing food revolution. In the following FAQ, we tackle a fundamental question: What is a GMO?
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At a Glance

Scientifically speaking, there is no such thing as a "genetically modified organism" or GMO; genetic modification is a process rather than a final product. GMO has become widely embraced as shorthand to refer to a plant or animal with new traits that has been created through modern genetic manipulation, often through transgenesis, in which genetic material from unrelated species are combined or synthetic or heavily modified DNA has been inserted into an organism's genetic code. But developing an all-encompassing, scientifically accurate definition for this highly-politicized term is difficult, if not impossible, posing challenges for regulators.

For centuries, farmers have used breeding to modify the genetics of plants, searching for ways to improve traits that include yield, disease resistance and flavor. Some of those breeding techniques, including wide cross breeding and mutagenizing seeds using radiation or chemicals, involved years of laboratory tinkering, but are not considered GMOs as it's commonly used. Advancements in biotechnology over recent decades have given breeders the ability to exert greater and more precise control over the breeding process. Today, the

seeds genetically engineered by companies represent the majority of what's planted in U.S. farmlands, particularly in grain crops. The foods that result from them are popularly referred to as GMOs.

Science and Politics

What constitutes a GMO? The modern world of plant and animal breeding involves a wide range of technologies, many of them accelerated and more precise versions of ones that have been around for centuries. As a consequence, many scientists have rebelled against using the term "GMO" to describe modern breeding techniques, as the acronym was created by biotechnology critics in an attempt to stigmatize genetic engineering by using the presumably scary, other-worldly term "organism." The desire to regulate genetically modified foods and products has resulted in the creation of several often contradictory definitions of GMOs.

The United Nations Cartagena Protocol on Biosafety an international agreement (which the US has not signed) designed to ensure the safe handling, transportation and use of genetically engineered crops in 1996 used the term LMO instead of GMO:

A Living Modified Organism (LMO) is defined as any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology. In everyday usage LMOs are usually considered to be the same as GMOs, but definitions and interpretations of the term GMO vary widely.

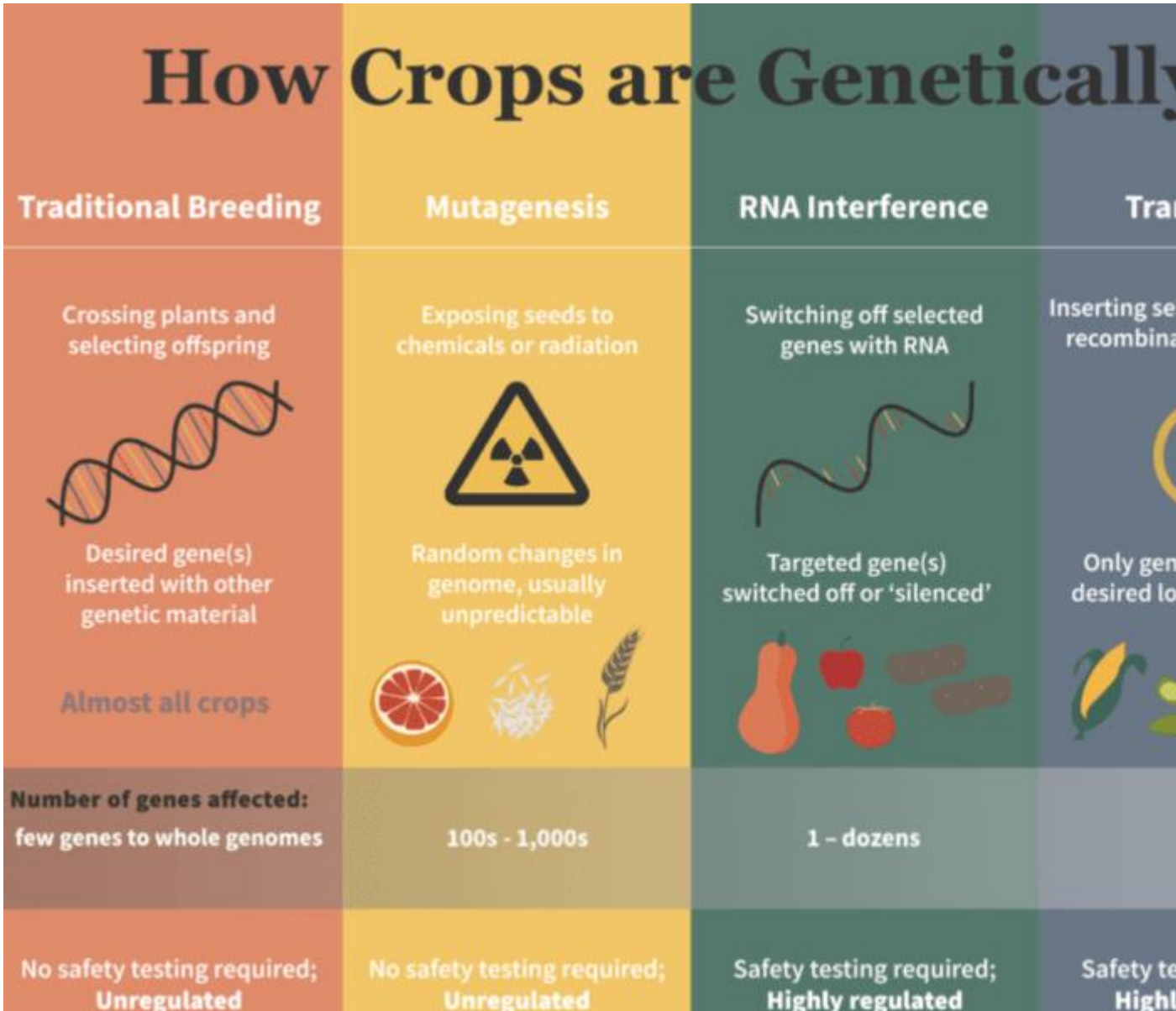
The Pew Initiative on Food and Biotechnology, 2001, did not define the acronym GMO but defined biotechnology as:

"…the use of recombinant DNA technology to transfer genetic material from one organism to another." The resulting organism is referred to as transgenic.

The European Food Safety Authority (EFSA) has adopted this one:

The term genetically modified organism (GMO) means an organism in which the genetic material has been altered in a way that does not occur naturally through fertilisation and/or natural recombination. GMOs may be plants, animals or micro-organisms, such as bacteria, parasites and fungi.

Drawing on those definitions, the US law defines a GMO not as any crop in which the genetic material has changed over time, but when a food "contains genetic material that has been modified through in vitro recombinant deoxyribonucleic acid (DNA) techniques; and for which the modification could not otherwise be obtained through conventional breeding or found in nature." Older techniques and also anything modified with the newest gene-editing techniques are exempt. In short, GMO is lingua franca for transgenic via rDNA.



There are numerous problems with these definitions, not the least of which is that we now know that all organisms (including humans) are natural transgenics–the genetic product of combining genetic material from different species. The classic definitions also include techniques that have been utilized in agriculture for decades pre-dating the introduction of the first genetically engineered crops in the 1990s. They imply that all GMOs must be made "in a laboratory," which is untrue. They also imply that only GMOs are altered "in a laboratory," which is not accurate, and that laboratory breeding is somehow unnatural, which if true would mean that many modern versions of foods are unnatural. For example, nematode resistant tomatoes were first generated in the 1940s using a plant breeding technique called embryo rescue "in a lab" with genes from a wild plant species—half a century before rDNA. Embryo rescue, cell fusion, chemical/physical mutagenesis and a lot of other techniques are "unnaturally" performed "in the lab" but are not classified as GMOs. Much of the attention given to GMOs has focused on plants or animals in which genetic material from unrelated species are joined the use of so-called foreign genes. Such transgenic pairings have resulted in products, including soybeans, corn and cotton, that are resistant to certain herbicides. However, this phenomenon also occurs in nature, albeit on a more limited basis.

The sweet potato, for example, is a result of nature's own transgenic breeding. But it's not the only one. A 2019 study revealed that 39 plant species qualify as natural GMOs. And since at least the 1930s, plant breeders have performed "wide cross" hybridizations, in which large numbers of "foreign" genes have been moved across what used to be thought of as "natural breeding boundaries" to create plant varieties that cannot and do not exist in nature. As geneticist Henry Miller has noted,

Most of these hybridizations, which are performed between organisms of different species or genera, produce a non-viable zygote, so laboratory scientists devised mechanical and biochemical ways to "rescue" the embryos and enable them to develop. Common commercial crops derived from wide crosses include tomato, potato, sweet potato, oat, rice, wheat, corn, and pumpkin, among others.

The main problem with the widely-circulated definitions of GMO is that they perpetuate the GMO=unnatural and unnatural=GMO misconception–a framing popular with agricultural biotechnology critics. As *Grist*'s Nathanael Johnson has written, current popular definitions of GMOs do not hold up under scientific scrutiny. There is no clear definition, he concluded, calling it a 'social construct' that has come to represent larger social and environmental concerns.

People argue about GMOs because they are worried about safety, or environmental integrity, or human rights. Like porn, GMOs defy strict definition because, like porn, GMOs are a cultural construct with borders that shift with the times. Perhaps the most accurate definition of GMO is social and contextual: Organisms breed in a way that people find threatening.

GMO ambiguities abound in other ways. In crop biotechnology, while the seed is genetically modified, in some cases the final product is identical to the non-GMO variety, rendering the term problematic. There is no genetic difference, for example, between GMO and non-GMO sweet corn, sugar made from GMO sugar beets versus non-GMO cane sugar or oils made from GMO soybeans, which are processed (e.g. syrup, oil, starch from maize or sugar from sugar beet do not contain DNA.)

Many food additives rely on genetically modified fungi or bacteria, but are not considered GMOs. Most hard cheeses use a GM enzyme, which the non-GMO Project says qualifies them as GMOs, but Vermont's labeling law did not. GM microorganisms are used to make many vitamins, often used to fortify products; the Non-GMO Project considers them GMOs, but European regulators and most labeling laws do not.

Janet Carter, a soil scientist and longtime consultant to Greenpeace on its anti-GMO efforts, writing for GMWatch, has challenged Johnson's view that there is no such thing as a GMO.

It's important here to differentiate between novel combinations of genetic material that happen occasionally or rarely in nature, and the routine production of organisms with novel combinations of genetic material that are produced with genetic engineering.

Carter rejects mutagenesis, in which plants are altered in laboratories using chemicals or radiation as an example of a GMO, contending it is "random" and not "directed." As do many anti-GMO activists, she contends that a "GMO is not defined by the presence of 'foreign genes' positioning biotech critics to oppose new breeding technologies (NBTs), which do not necessarily involve transgenics. Many critics of crop biotechnology are concerned that CRISPR and other NBTs will escape the restrictive regulations that have stifled modern crop innovations.

The United States does not employ a specific legal definition of a GMO. It uses a patchwork of regulations and oversight by the Department of Agriculture, Food and Drug Administration and Environmental Protection Agency to address the subject. The focus is on

the products themselves (and whether they are safe), rather than the way in which they were made. According to the FDA:
"Genetic engineering generally refers to the use of recombinant DNA (rDNA) techniques to introduce new characteristics or traits into an organism."
Under this definition, the USDA has chosen not to regulate gene-edited crops as GMOs.

The Takeaway

Defining a GMO is much like the oft-used example of society's attempts to define pornography. The definition can vary significantly from one person or organization to the next. That's a key reason why scientists generally shun the use of the term GMO it lacks specificity and is more a political term than a scientific one. Why does it matter that the term is so vague? As Nathanael Johnson has written:
… [O]nce people understand how mushy the definition of GMOs really is, they start to realize how hard it would be to make substantive change by regulating GMOs. There are GMOs that reduce pesticide spraying, and GMOs that increase pesticide spraying. There are GMOs designed to serve monoculture, and GMOs made for small farmers with mixed plots. There are GMOs made to work hand-in-hand with herbicide, and non-GMOs made to work hand-in-hand with herbicide. There are GMOs controlled by big corporations, and GMOs given away for free by universities. … The question "to GMO or not to GMO" isn't really useful. The real question we should be asking is this: How fast, and in what directions, should agricultural innovation advance?

GLP Articles

- Infographic: Are genetically engineered crops less safe than classically-bred food?, Kayleen Schreiber, February 19, 2019
- Viewpoint: Why the USDA decided not to over-regulate CRISPR crops—and what it means for agriculture's future, Val Giddings, April 5, 2018
- Why the concept of GMOs is meaningless, Giovanni Tagliabue, January 10, 2016
- GMO myth busting: Crops (and humans) safely composed of 'foreign' genes, Jon Entine, May 26, 2015
- Avoiding 'foreign genes' trap: Tale of two potatoes highlights new era of GE crops, Rebecca Randall, January 6, 2015
- What's so "natural" about "natural crop breeding? Jon Entine, October 30, 2014
- GMO 'foreign gene' fears? Breeders incorporating unknown DNA into food crops for centuries, Curtis Hannah

Additional Resources

- Widespread Occurrence of Natural Genetic Transformation of Plants by Agrobacterium, Tatiana V Matveeva and Léon Otten, Plant Mol Biol, November 2019
- What's in a Name? Plenty, if It's a 'GMO', Henry Miller, National Review, July 20, 2016
- The meaningless pseudo-category of "GMOs", Giovanni Tagliabue, EMBO Reports, November 12, 2015
- To regulate GMO we must define GMO, Anastasia Bodnar, Biology Fortified, November 5, 2015
- What Is A GMO? Genetically Modified Foods Continue To Confuse Consumers, Mary Clare Jalonick, Associated Press, May 9, 2014
- Restrictions on Genetically Modified Organisms: United States, Luis Acosta, senior legal information analyst, Library of Congress. March 2014

- Genetically Engineered Crops in the United States, Jorge Fernandez-Cornejo, Seth Wechsler, Mike Livingston, and Lorraine Mitchell, US Department of Agriculture, February 2014
- What is GMO? The Non GMO Project
- Genetically Modified Organisms, European Food Safety Authority
- Frequently Asked Questions on the Cartagena Protocol, Convention on Biological Diversity

https://geneticliteracyproject.org/gmo-faq/glp-tackles-one-of-the-most-frequently-asked-biotech-questions-what-are-gmos/?mc_cid=3b97427fac&mc_eid=d1b028cc70