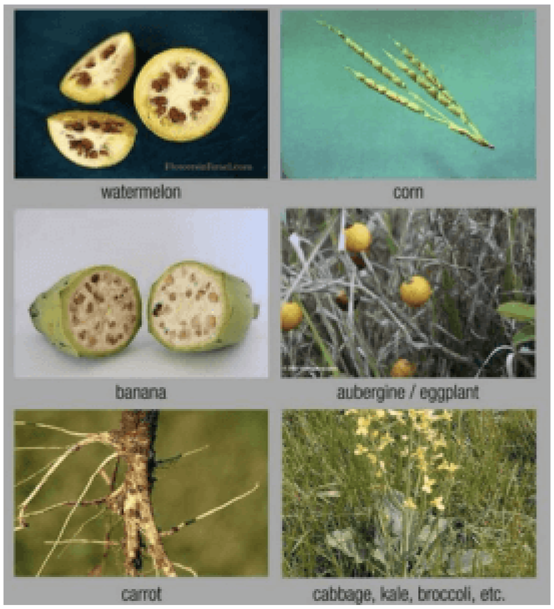
How does genetic engineering differ from conventional breeding?

Scientists challenge the concept of “foreign genes.” Humans have dinosaur genes and genes from every species on earth in our DNA. Humans and bananas share around half their DNA; that doesn’t make humans “half banana” — nor does it make those shared genes “banana genes.” They are just genes and they are useful to bananas and humans in different ways. While humans and nematodes and dogs and birds share genes, they express themselves differently. That’s why scientists are uncomfortable with the term “foreign genes” it’s scientifically meaningless.

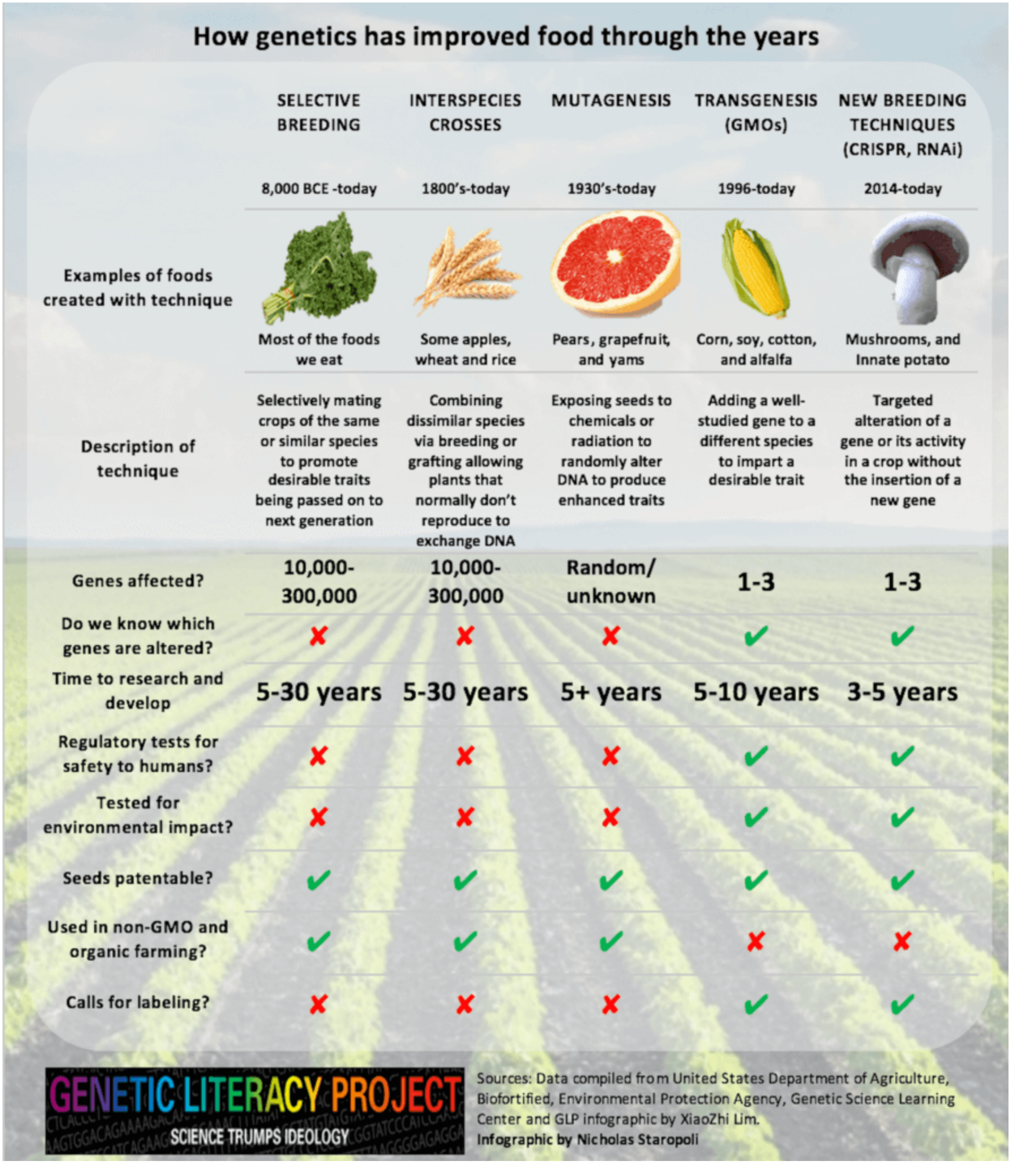


Early ancestors of several modern food staples.

Most plant scientists view transgenesis moving genes between unrelated organisms as just another step in the 10,000-year history of evolution and human-guided plant breeding. Nature does it naturally. Sweet potatoes were modified at least 8,000 years ago when bacteria inserted its DNA into the wild ancestors of today’s vegetable, conferring its sweeter, more edible flavor. Farmers have been accidentally making GMOs for millennia by grafting plants, such as a tree that bears delicious fruit with one that has disease-resistant roots. Cells on either side of a graft swapped the entire nuclease of a cell, energy-generating mitochondria and chloroplasts — organelles that carry out photosynthesis and have their own small genome.

“It’s genetic engineering done by mother nature,” said Ralph BockÂ of the Max Planck Institute of Molecular Plant Physiology in Potsdam, Germany.

Modern forms of genetic engineering, most scientists say, are a more precise way to add desirable or subtract undesirable traits. Throughout history, breeders have manipulated plant development through sexual crossing. Almost all the foods we eat today are not “natural” they have been modified, or in some cases created from almost inedible wild plants.



How genetics has improved food through the years

	SELECTIVE BREEDING	INTERSPECIES CROSSES	MUTAGENESIS	TRANSGENESIS (GMOs)	NEW BREEDING TECHNIQUES (CRISPR, RNAi)
	8,000 BCE -today	1800's-today	1930's-today	1996-today	2014-today
Examples of foods created with technique	Most of the foods we eat	Some apples, wheat and rice	Pears, grapefruit, and yams	Corn, soy, cotton, and alfalfa	Mushrooms, and Innate potato
Description of technique	Selectively mating crops of the same or similar species to promote desirable traits being passed on to next generation	Combining dissimilar species via breeding or grafting allowing plants that normally don't reproduce to exchange DNA	Exposing seeds to chemicals or radiation to randomly alter DNA to produce enhanced traits	Adding a well-studied gene to a different species to impart a desirable trait	Targeted alteration of a gene or its activity in a crop without the insertion of a new gene
Genes affected?	10,000-300,000	10,000-300,000	Random/unknown	1-3	1-3
Do we know which genes are altered?	✘	✘	✘	✔	✔
Time to research and develop	5-30 years	5-30 years	5+ years	5-10 years	3-5 years
Regulatory tests for safety to humans?	✘	✘	✘	✔	✔
Tested for environmental impact?	✘	✘	✘	✔	✔
Seeds patentable?	✔	✔	✔	✔	✔
Used in non-GMO and organic farming?	✔	✔	✔	✘	✘
Calls for labeling?	✘	✘	✘	✔	✔

GENETIC LITERACY PROJECT SCIENCE TRUMPS IDEOLOGY

Sources: Data compiled from United States Department of Agriculture, Biofortified, Environmental Protection Agency, Genetic Science Learning Center and GLP infographic by XiaoZhi Lim.
Infographic by Nicholas Staropoli

Conventional breeding and genetic engineering do not describe single techniques. Instead, they encompass a spectrum of breeding methods used to achieve the same goal: the modification of a plant's genetics to create something that tastes better, has stronger pest resistance, is more nutritious, etc.

Breeders employ a wide range of techniques in the development and refinement of plants and animals.

Interspecies crosses, also known as **hybrids,** have been occurring since the 19th century. The result is the mixing, through sexual reproduction of two animals or plants of different breeds, varieties, species or genera that would never mate in nature (although some natural hybrids have occurred). Modern and ancient forms of wheat, peppermint and a tangelo are examples.

Polyploidy, which is chemically induced hybridization, increases the amount of genetic material in a plant to do things like increase fruit size or improve fertility. Examples are seedless watermelon and kiwi fruit. **Protoplast fusion** is a technique in which plant cells are fused, often using an electric field, to move beneficial traits from one species to another.

Mutagenesis, developed in the 1930s and still used today as an "acceptable" alternative to genetic engineering," involves radiating or chemically dousing seeds in laboratories to create thousands of unknown random mutations in the hopes of finding beneficial traits. More than 3,000 plants have been produced this way, including the sweet Ruby and Rio Red grapefruits (irradiated with thermal neutrons), versions of durum wheat used in premium Italian pasta, Calrose Rice and the Osa Gold pear.

Although all of the above listed techniques have been used by farmers and scientists to create fruits, vegetables and other plants that were not found in "nature," they are all considered "conventional" and undergo no special safety or allergen tests. The food products of these random gene alterations can be sold as organic despite their "unnatural" origins.

Genetic engineering emerged in the 1970s and 1980s. Molecular techniques were developed to move precisely target individual genes in plants rather than rely on scattershot techniques like mutagenesis. Scientists considered it the next-step evolution in gene breeding but many advocacy groups did not. Despite the fact that transgenesis was more precise than conventional breeding, it was subjected to intense regulatory review.

Transgenesis, usually usingÂ agrobacterium-mediatedÂ transformation, is the most common form of genetic engineering. It uses a harmless bacterium *and* has the ability to transfer a portion of its DNA, carrying a new desirable trait on its back, into a plant's DNA. This technique was used to develop the overwhelming majority of GMO drugs, such as insulin, used safety (and uncontroversially) for decades,as ell as crops including herbicide tolerant and insect resistant varieties.

RNA interference (RNAi) techniques allow scientists to switch off specific genes within the plant itself a form of cisgenesis (which does not involve mixing of species) to eliminate undesirable traits. Recombinant DNA techniques allow them to insert genes to add desired traits. The Arctic Apple and Innate potato whose genes for browning were silenced, are products of RNAi technology, and are not regulated as GMOs.

CRISPR/Cas9 and other gene editing techniques are the newest, most precise forms of genetic modification. These allow researchers to move around or delete targeted regions of a genome and introduce variations, to develop crops or animals with desired traits. There is a great deal of regulatory uncertainty over genome editing critics of GMOs are pushing to have cisgenic breeding regulated in the same way as traditional transgenic crops. Several products, including a mushroom that resists browning, have escaped the scrutiny of the USDA, which has ruled that it doesn't need to approve new varieties created without the use of foreign DNA. However, products designed as food for humans are still reviewed by the Food and Drug Administration.