AGRICULTURAL BIOTECHNOLOGY

Questions & Answers

Agricultural Research Service, USDA

What is biotechnology?

- Methods of using plants, animals, or microbes, either wholly or in part, to make or modify a product or change existing species.

What is genetic engineering?

- A biotechnological process in which the traits or characteristics of an organism are changed by transferring individual genes from one species to another or modifying genes within a species.

What are genetically modified organisms (GMOs)?

- Today's domesticated plants and animals are the result of selective breeding programs. All these organisms have been 'genetically improved' for traits such as yield, or disease and insect resistance.
- Today's breeders define a genetically modified organism as an organism that has been modified using traditional plant breeding techniques or genetic engineering techniques in which only a small piece of one organism's genetic material (DNA*) is inserted into another organism.
- In popular usage, the term 'genetically modified organism', or GMO, refers only to an organism produced by genetic engineering.

*DNA is a molecule which is the basis of heredity. Each gene is a section of DNA that occupies a specific place on a particular chromosome and influences the inheritance and development of some characteristic.

What types of GMO products are used today?

- Medicines (e.g. diagnostic tools and drugs such as insulin)
- Plants (e.g. insect, disease, and herbicide resistant plants)
- Enzymes for food production (e.g. cheese)
- Fuels and solvents (e.g. ethanol)

What types of GMO products are being used in agriculture?

Currently, the only products available to farmers are those used for pest control:

- Soybeans, cotton, corn, and canola engineered to be resistant to an herbicide, including an estimated 90% of the soybeans grown in New York.
- Corn, cotton, and potatoes engineered to produce bacterial proteins (Bt) that are toxic to insects.
- Squash and papaya engineered to resist viruses.

It is estimated that 60-70% of packaged grocery products contain some GMO ingredients (such as corn syrup, canola or soybean oil). The US National Academy of Sciences recently stated there is "no evidence that foods on the market are unsafe to eat as a result of genetic modification."

Why have growers adopted the products of biotechnology?

- Growers have adopted herbicide resistant crops because they believe they can manage weeds more efficiently and adopt better soil conservation practices (no-till and minimum-till practices).
- In the case of Bt plants, growers have indicated they achieve better insect control and reduced use of synthetic chemical insecticides in some cases.
- Genetically engineered virus-resistant plants are, in some cases, the only reliable means for protecting the crop against viruses.

What are the potential benefits and risks associated with the products of agricultural biotechnology?

	POTENTIAL BENEFITS	POTENTIAL RISKS
Farmers	Increased productivity Reduced costs of production Better pest management New agricultural products	Restricted markets Increased consolidation of the food industry
Consumers	Lower food prices Enhanced food quality Elimination of allergens New food products	Long term food safety Unexpected allergens
The Environment	Fewer harmful pesticides Increased biological control practices	Spread of GMOs into non-GMO crops

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GMOs must be evaluated on a case by case basis through research to resolve questions about risks and benefits and compared to current production practices.

8/00

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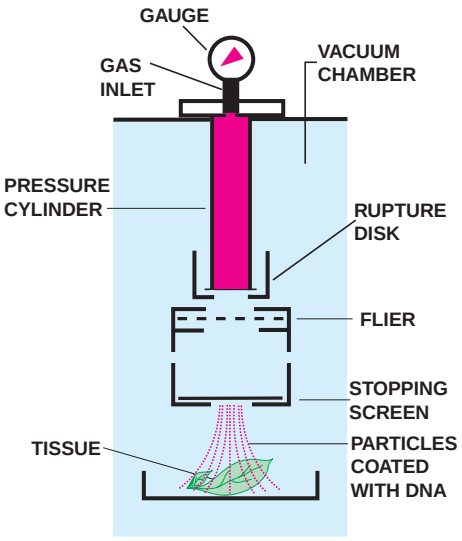
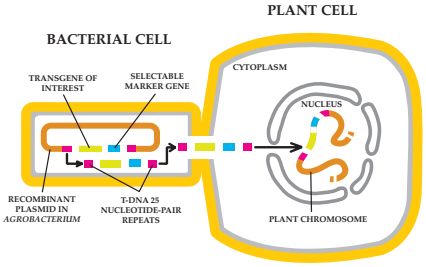
Tools & Methods

How are genes transferred to crop plants?

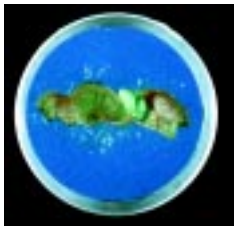
The **"Gene Gun"** is a popular tool used world-wide for genetically engineering plant cells. Researchers at Cornell's Ithaca and Geneva campuses developed the technology in 1986.



Gene transfer by *Agrobacterium tumefaciens* is another powerful tool for plant genetic engineering. The process is used routinely to move genes into dicotyledonous plants.

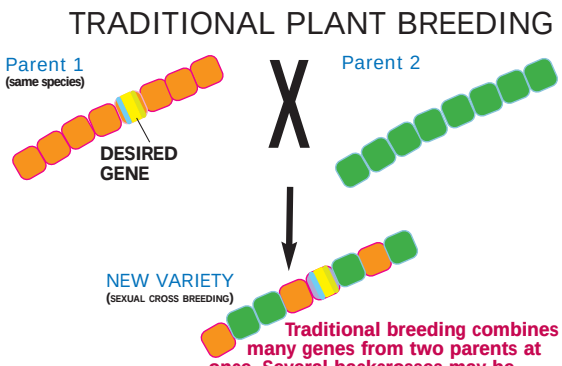


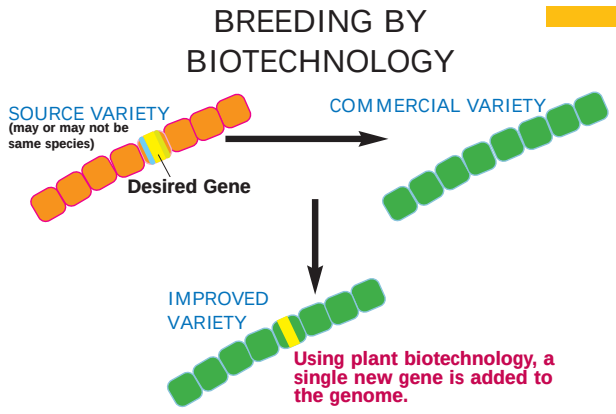
Tissue culture is a major component of plant genetic engineering and allows selection of plants transformed with useful genes.



What's the theory behind genetic improvement of plants through agricultural biotechnology?

This new technology is an extension of traditional breeding techniques that allow transfer of **only** known, well-characterized genes into plants.





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Applications

How can genetically engineered crops help farmers and consumers?

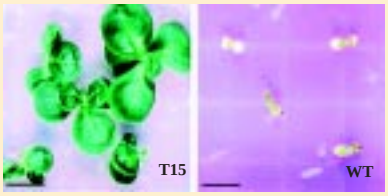
Produce crops that resist insects and diseases and tolerate herbicides.

Virus resistant transgenic squash [*background*] vs. diseased squash [*foreground*]. (Reference: Tricoli et al., 1995. Biotechnology 13: 1458-65.)

Bt corn genetically engineered to resist the European corn borer [*inset*]. (Reference: Estruch et al., 1997. Nature Biotechnology 15: 137-141.)

Transgenic potatoes [*left*] vs. non transgenic potatoes [*right*] challenged with fungal pathogen *Rhizoctonia solani*. (Reference: Lorito et al., 1998. Proc. Natl. Acad. Sci., USA 95: 7860-7865.)

Resist adverse soil and weather conditions.



Transgenic plants (T15) being tested in tissue culture for resistance to high temperature and drought vs. heat sensitive non transgenic plants (WT). (Reference: Murakami et al., 2000. Science 287:476-479)

Transgenic plants have been developed for enhanced phosphorus uptake and therefore less fertilizer use. (Reference: Lopez-Bucio et al., 2000. Nature Biotechnology 18: 450-453.)

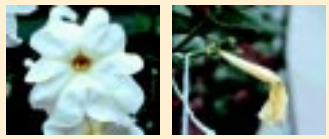
Transgenic papaya [*left*] resistant to aluminum toxicity and drought vs. non-transgenic plants [*right*] in tissue culture. (Reference: De la Fuente et al., 1997. Science 276: 1566-1568)

Improve nutritional quality and marketability.

Transgenic apples can delay fruit ripening and extend storage life.

Genetically engineered corn can resist insect pests that attack stored grains and farm produce. (Reference: Kramer et al., 2000, Nature Biotechnology, 18:670-4)

Rice genetically engineered to produce provitamin A (beta carotene) can improve child nutrition in Third World countries, preventing blindness and strengthening resistance to diseases. (Reference: Ye et al., 2000. Science 287: 303-305.)



Transgenic petunias [*left*] can exhibit longer shelf life as cut and potted flowers. (Reference: Wilkinson et al., 1997 Nature Biotechnology 15: 444-447.)

Transgenic melons can display extended storage life and improved quality. (Reference: Ayub et al., 1996. Nature Biotechnology 14: 862-866.)

Develop 'agri-ceuticals' for improving health and the environment.

Genetically engineered beans are being developed as an alternative to animal-based vaccines against MEV (mink enteritis virus). (Reference: Dalsgaard et al., Nature Biotechnology, 1997, 15, 248-252.)

Transgenic bananas containing immunoglobulins or IgGs are being developed as edible vaccines. (Reference: Arntzen, CJ 1998. Nature Medicine 4: 502-503.)

Poplar trees are being genetically engineered for remediation and breakdown of toxic mercury from the soil. (Reference: Rugh et al., 1998. Nature Biotechnology 16: 925-928)

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Like all new technologies, these crops must be evaluated for their benefits and risks and compared to current production practices.

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AGRICULTURAL BIOTECHNOLOGY

The Debate

Agricultural Research Service, USDA

What are the issues regarding biotechnology products?

Agricultural Research Service, USDA

Food production systems are complex whether they be conventional, organic, or involve biotechnology. They entail questions of technology and society, and fundamental values for each of us. It is important that we understand what the issues are and become engaged in the debate.

Agricultural Research Service, USDA

The attributes of a GMO should be evaluated on a case by case basis for its potential benefits and risks, not simply on the technology used to produce the GMO.

Techniques of Traditional Breeding vs. Genetic Engineering

OPPONENTS

"Genetic engineering is imprecise and other unanticipated traits may also be introduced into the new plant. Traditional breeding allows only crosses within a species and thus provides some protection against unanticipated outcomes."

PROPONENTS

"Genetic engineering allows breeders to move specific traits and leave behind the other unwanted traits, thus it is more precise. This can shorten the time for developing new varieties. In some cases a desirable trait (e.g. disease resistance) can only be incorporated using genetic engineering."

ONGOING DIALOGUE

Traditional breeding techniques introduce many new genes into a variety but those genes come from the same or a very closely related species. Genetic engineering introduces one or a few new genes into a new variety but those genes can come from any species closely or distantly related or completely unrelated. Is one of these processes inherently different or better than the other?

NYSAES, Geneva, NY

Moving Foreign Genes into Plants

OPPONENTS

"I don't want foreign genes in my food. I have heard that scientists are putting 'fish genes' into tomatoes to prevent them from freezing and it sounds wrong to me."

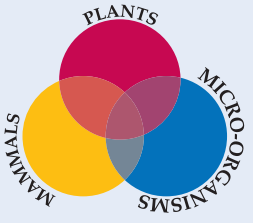
"Genes act with other genes in an organism and we may not know the results."

PROPONENTS

"A gene is nothing more than a piece of DNA that codes for a particular protein. Plants and animals share much of the same DNA. More accurately a 'fish gene' is a cold tolerance gene that occurs in many species. "

ONGOING DIALOGUE

The genetic code is universal—all traits of all living organisms are based on the same DNA code of four 'letters' assembled into the instructions (genes) for the development and structure of each organism. Changes in genes occur naturally through mutation. Is any particular DNA sequence 'foreign' or simply another variation on an ever-changing universal genetic code?



Biological organisms share most of the same genes common to all life forms in addition to many other genes for specific traits.

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These are some of the issues and viewpoints. What are the important issues for you?

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AGRICULTURAL BIOTECHNOLOGY

The Debate

Agricultural Research Service, USDA

How Does the Technology Affect Consumers and Food Safety?

OPPONENTS

"Long term feeding studies have not been done on plants that have been engineered to express new traits and so there is no reason to believe they are safe we need to see the data."

"Any products produced through genetic engineering should be labeled so people have a choice. This especially applies because of potential allergic reactions, religious beliefs, and/or eating habits (e.g. organic, vegan)."

PROPONENTS

"It is not the process of engineering that should be judged, but rather the final product of that engineering. The present products have been judged to be safe by the Food and Drug Administration. "

"Labeling of products as 'GMO' will provide unwarranted concern and mislead the public since they do not produce any increased risk."

"Allergenicity tests are done before a product enters the market. Kosher and halal regulations by and large support the use of GMOs in food products."

ONGOING DIALOGUE

If common foods were subjected to common toxicological tests, they might prove harmful or anti-nutritional. So, what should be a logical procedure for testing traditionally bred or genetically engineered varieties? How can our regulatory agencies hold all food crops to the same food safety standard?

How Does the Technology Affect the Environment?

OPPONENTS

"We don't know the long-term environmental effects of growing these plants. Some of the characteristics of these engineered plants might spread to wild plants or cause other unanticipated effects. "

"Who will pay for the unintended consequences of GMOs?"

PROPONENTS

"Plants that are resistant to insects and diseases will allow growers to use less harmful pesticides and implement soil conservation practices that will benefit the environement."

"As long as people want blemish-free food products, some form of pest control will be necessary."

ONGOING DIALOGUE

Each GMO crop will have its own set of environmental risks and benefits and these must be documented through a scientific process. Environmental risks of biotechnology must be compared with the risks of currently used technologies. As with many technologies, the public has generally shouldered the major burden of the cost of past environmental consequences of traditional agriculture. Should this be the case?

Environmental concerns must be scientifically addressed for traditionally bred and genetically engineered crop varieties.

Agricultural Research Service, USDA

How Does the Technology Affect the Farmer?

OPPONENTS

"Farmers are being caught in the middle. This new form of technology (GMOs) is being forced on farmers but now the public may not accept the products and growers may not be able to sell their crops. "

"Other alternatives such as organic agriculture are more acceptable to the public. Growers should consider developing this form of agriculture."

PROPONENTS

"Farmers are struggling because of many issues and policies outside of biotechnology. Biotechnology will make farming more efficient and will provide some new forms of agricultural products such as plants which produce fuels, medicines, plastics, etc. GMOs are not the only form of agriculture that will provide food and fiber but they will be increasingly important."

ONGOING DIALOGUE

One size will not fit all. The medical field has its traditional and modern medicine therapies. It is likely that our agricultural production will encompass several different systems such as traditional large scale farming practices, 'organic agriculture', more 'biologically based agriculture' and agricultural systems which include GMOs.

Agricultural Research Service, USDA

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These are some of the issues and viewpoints. What are the important issues for you?

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AGRICULTURAL BIOTECHNOLOGY

The Debate

Agricultural Research Service, USDA

Government Regulations

OPPONENTS

"Genetically modified organisms will require special regulations and we doubt that our regulatory agencies can handle this. In Europe already the public does not seem to trust their agricultural and food safety agencies because of the misinformation they have provided about such issues as 'mad cow' disease."

PROPONENTS

"The Environmental Protection Agency, Food and Drug Administration and US Department of Agriculture all work together to regulate the safe use of biotechnology products. The public trusts these agencies that have helped to protect us against serious food hazards. "

ONGOING DIALOGUE

There is considerable public discussion about the need for more careful regulatory oversight of genetically engineered crops, and also about the need for labeling. What sort of testing do you think should be required of genetically engineered varieties? Should it be any different from that required for new crop varieties bred in other ways? Is labeling of food products derived from genetically engineered organisms worth the extra cost or effort required? Will the public really pay much attention to such labels?

The US Food & Drug Administration (USDA), Environmental Protection Agency (EPA), and Department of Agriculture (USDA) have established regulations that govern the production and consumption of GMOs.

Regulatory Oversight in Biotechnology

Agency	Products Regulated
USDA	plant pests, plants, veterinary biologics
EPA	microbial/plant pesticides, new uses of existing pesticides, novel microorganisms
FDA	food, feed, food additives, veterinary drugs, human drugs and medical devices

New Trait/Organism	Regulatory Review Conducted by	Reviewed for
Herbicide tolerance in food crop	USDA EPA FDA	Safe to grow Safe for the environment Safe to eat
Insect resistance in in food crop	USDA EPA FDA	Safe to grow Safe for the environment Safe to eat
Viral resistance in food crop	USDA EPA FDA	Safe to grow Safe for the environment Safe to eat
Herbicide tolerance in ornamental crop	USDA EPA	Safe to grow Safe for the environment
Modified oil content in food crop	USDA FDA	Safe to grow Safe to eat
Modified flower color in ornamental crop	USDA	Safe to grow
Modified soil bacteria that degrade pollutants	EPA	Safe for the environment

Patents and Control of the Technology

OPPONENTS

"There is something fundamentally wrong about being able to patent a life form and then use it to develop a product such as an insect or herbicide resistant plant."

"Multinational corporations are developing these agricultural products and their motivation is profit, not social responsibility."

"Farmers who plant biotechnology product seeds can't reuse their seeds."

PROPONENTS

"Capital is required for any product to be developed in our market-based economy. The costs must be recouped from those who use the product and many farmers already buy new hybrid seed each year. In 1985, the US Patent and Trademark Office allowed the patenting of genetically engineered plants, seeds and plant tissue. Companies claim that they can only recoup their development costs with such patents. Profit and social responsibility are not mutually exclusive."

ONGOING DIALOGUE

Patent questions are some of the most complex issues facing agricultural and medical sciences and there are court challenges to our present patent laws. Our economy is based on the development of useful products and new businesses. Multinational corporations are increasingly common in all industries and a society needs to evaluate their effects on product development as well as the overall effect on the society and its values.

Who Decides on the Products?

OPPONENTS

"Decisions are being made by others and the public has not had an adequate opportunity to learn about these technologies and whether they should support them. The public has not been engaged in the decision making process."

PROPONENTS

"Fundamentally, the creation of a new crop using genetic engineering is no different from the types of crops that have been created before. Like all new products, it is ultimately the public who will decide whether they are accepted."

ONGOING DIALOGUE

The public will make the final decision about the role of biotechnology products in agriculture, so we all must become knowledgeable about the real issues and let our voices be heard. Educational institutions are in a unique position to help shed some light on the debate by identifying the issues and informing the public about what we do and do not know about these issues. The public must become informed and engaged and make the final decision.

Agricultural Research Service, USDA

These are some of the issues and viewpoints. What are the important issues for you?

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AGRICULTURAL BIOTECHNOLOGY

Glossary & References

Glossary of Plant Breeding Terms

Biotechnology
Methods of using plants, animals, or microbes, either wholly or in part, to make or modify a product or change an existing species.

DNA
Any of the various nucleic acids that are the molecular basis of heredity. Each gene is a section of DNA that occupies a specific place on a particular chromosome.

GE Foods
Abbreviation for food produced through genetic engineering.

Gene
Word coined in 1909, section of DNA that occupies a specific place on a particular chromosome. Each gene influences the inheritance and development of some characteristic.

Gene Splicing
Taking segments of DNA from one organism and putting them into the DNA of another organism. Synonymous with recombinant DNA technology

Genetic Engineering
A biotechnological process in which the traits or characteristics of an organism are changed by transferring individual genes from one species to another or modifying genes within a species.

Genetically Modified Organism (GMO)
An organism that has been modified using traditional plant breeding techniques or genetic engineering techniques of gene transfer, in which only a small piece of one organism's genetic material (DNA) is inserted into another organism. In popular usage, the term 'genetically modified organism', or GMO, refers only to an organism produced by genetic engineering.

Genetics
First coined in 1906, it is the science dealing with heredity.

Recombinant DNA Technology
The process of recombining genes bearing a chosen trait into the molecules of a new plant.

Transgene
The specific gene moved from one organism to another using recombinant DNA technology.

Transgenic plant
Plants that have been genetically modified using recombinant DNA technology to introduce a gene from either the same or a different species.

For Further Reference

The Alliance For Better Foods – Improving Agriculture Through Biotechnology
http://www.betterfoods.org/

Applications of Biotechnology to Crops: Benefits and Risks
http://www.cast-science.org/biotc_ip.htm

Biotechnology — The Farm Perspective
http://www.fb.com/issues/biotech/biotech_farmers.html

Center for Global Food Issues
http://www.cgfi.com/

The Council for Biotechnology Information
http://www.whybiotech.com/main.html

Crop Biotechnology: Benefits, Risks, and Ownership
http://www.rockfound.org/news/03062000_cropbiotech.html

Food and Feed Safety: Roundup Ready Soybeans
http://www.biotechbasics.com/product_information/rr_soy_foodsafe.html

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http://vm.cfsan.fda.gov/~lrd/biocon.html

"Genetic Engineering, Food, and Our Environment."
1999. Luke Anderson. Chelsea Green Publishing Company, White River Junction, Vermont.

Greenpeace
http://www.greenpeace.org/home.shtml

Laws, Regulations, Policies, and Responsibilities
http://www.aphis.usda.gov/biotechnology/laws.html

Regulatory Oversight in Biotechnology
http://www.aphis.usda.gov/biotech/OECD/usregs.htm

New York Times articles on Genetically Modified Foods
http://www.nytimes.com/library/national/science/health/gm-index.html

This Rice Could Save a Million Kids a Year
TIME magazine. July 31, 2000.

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