health applications and ethical and policy challenges such as banning them, equal access, genetic handicapping, and genetic lotteries.

Reiss, Michael J., and Roger Straughan. (1996). *Improving Nature? The Science and Ethics of Genetic Engineering*. New York: Cambridge University Press. Covers a broad range of ethical and theological concerns inherent in genetic engineering of microorganisms, plants, animals, and humans.

Suzuki, David, and Peter Knudtson. (1989). *Genethics: The Clash between the New Genetics and Human Values*. Cambridge, MA: Harvard University Press. The authors propose a set of genetic principles that emphasize individual rights and confidentiality with regard to genetic screening, caution in violating boundaries across species, and a ban on biological weapon development and the genetic manipulation of human germ cells.

GENETICALLY MODIFIED FOODS

The production of genetically modified foods has provoked an ethical debate about whether it is right to use technology to create new forms of plant and animal life that otherwise would not exist. However, throughout human history agricultural crops have been genetically modified. There is nothing "natural" about food crops because most of them would be unable to propagate or survive without human intervention. What have changed over the years are the technologies that have been used to bring about genetic modification.

In general, humans have used three methods to modify plants genetically.

Conventional Breeding

At one time farmers practiced selective breeding and cross-breeding, or what is termed conventional breeding. Conventional breeding is less precise and predictable and therefore arguably less safe than genetic modification or, more correctly, *transgenic* plant breeding. The process has worked well because humans practicing conventional plant breeding have been able to increase yields in agriculture and support a larger population and/or improve human nutrition. The high-yielding dwarf varieties of wheat and rice that produced the Green Revolution were the result of conventional breeding.

Until the twentieth century most plant and animal breeding was largely a matter of selection and cross-breeding. Occasionally crosses between separate species were made as a result of human action or an unexplained "natural" happening. Wheat is a product of two or three different transpecies crosses of plants with different chromosomal structures.

In the 1920s advanced pollination techniques were used to create hybrid maize, a major but accepted genetic modification that far outyielded normal or "natural" maize. However, seed saved from hybrid maize for planting reverts to its original form and yields much less than the hybrid does. This means that a farmer has to buy new seed each year, but the increased yield normally makes that effort worthwhile. Hybrid maize has become the number one food crop in Africa.

Mutagenesis

The next method in this technological continuum involved the use of nuclear radiation or chemical mutagens to bring about mutations. This method is called *mutagenesis* and has the least-predictable outcome of all forms of plant breeding, but the technology is accepted and has escaped the label *genetic modification* presumably because these techniques have been used for more than half a century. The only advantage of the powerful and sometimes lethal genetic mutagens is that they produce a great many more mutations than occur naturally, thus generating the variability that breeders need for finding and introducing new characteristics into their plants. The Food and Agriculture Organization/International Atomic Energy Agency's Mutant Varieties Database Register (December 2000) lists over 2,252 crops in the more than seventy countries in which these mutant varieties are used. Key varieties are grown and/or eaten in virtually every country. Barley used in commercial beers around the world as well as wheats used to make pasta are products of radiation mutation breeding.

Genetic Engineering

With the discovery of the structure of DNA (deoxyribonucleic acid) in the 1950s, followed over the decades by a greater understanding of the process of inheritance, the way became clear for transgenic technology, or genetic engineering. This allowed desirable characteristics expressed by a gene or a small group of genes from any organism to be transferred to another organism. By the early 1980s the first genetically engineered pharmaceuticals were released, and they have been followed by an increasingly sophisticated array of new drugs. By the late 1980s transgenic enzymes and bacteria were involved in the production of cheese, bread, wine, beer, and vitamins that are consumed on a daily basis by numerous people.

Biotechnology is done under precisely controlled conditions in which a gene, together with a marker, is incorporated in plant tissue, which then is grown in tissue culture to produce plants. At this stage the plant is subject to initial evaluation to ensure that the gene has been transferred successfully and stably and produces the desired trait and that there are no unintended effects on plant growth or quality.

The gene transfer process is far more precise than the other accepted procedures and allows desirable plant transformations to be performed that are not possible using conventional breeding.

Benefits

Since their introduction in the mid-1990s transgenic crops engineered for herbicide tolerance, by expressing a protein that is fully digestible by humans and other animals, have brought about a decline in pesticide use, something critics of those crops have long claimed to favor. There have been enormous benefits from plants engineered to resist certain pesticides. Modern conservation tillage (or reduced-, minimum-, or no-tillage) agriculture using pesticides for weed and pest control conserves water, soil, and biodiversity better than does any current or previous form of tillage. In addition, this method saves fuel and therefore releases less carbon into the atmosphere. Conservation tillage is improving soil and soil quality. Planting with a drill, possibly disking the field, preserves soil structure and vegetative cover and the diversity of life therein, such as earthworms and other life forms that often are destroyed by deep plowing and other older forms of conventional agriculture. Conservation tillage has led to a reduction in overall pesticide use as a less toxic broad-spectrum pesticide is substituted for multiple sprayings of an array of targeted pesticides and herbicides.

Popular Fears of the Dangers of Frankenfoods

Genetic modification or engineering of crop plants has generated far more adverse reactions than did the informed guesswork that preceded it. Those products have been called *Frankenfoods*, a pejorative term for genetically modified foods that evokes the film version of Doctor Victor Frankenstein's monster from the novel by Mary Shelley (1797–1851). The fears are based on the extraordinary power of this new technology but concentrate principally on two issues: concern for human health and concern for the environment. Exhaustive tests have been carried out to determine whether genetically modified crops carry an increased risk of allergic reactions or other effects in people who eat them. There is no evidence so far that this or any other adverse reaction or nutritional problem has been caused in consumers of these crops after nearly ten years of production on more than 400 million acres of products consumed by more than 1 billion people.

Damage to the environment has been postulated to be a possible result of growing transgenic crops. Fears include the escape of genes into related wild plants, adverse effects of insect toxins (in the case of crops with the Bt gene) on desirable insects, and transfer of antibiotic resistance. Several factors lessen the likelihood of damage to the environment. Some crop plants and their wild relatives are self-pollinated, and so there is no opportunity for gene transfer to take place. Others have no wild relatives in the local flora, and so the local environment does not have suitable gene recipients. Transfer of antibiotic resistance from transgenic plants into the soil microflora is very unlikely and has not been demonstrated convincingly. Even if there were transfer, these genes already are ubiquitous in the soil microflora.

The most prominent public phobias in developed countries involve *chemicals* (a code word for industrially produced chemicals), which are all assumed to be carcinogenic; and radiation, which is assumed to cause cancer and mutations. One wonders why there has been no outcry about the use of *chemicals* and radiation in plant breeding, particularly in light of the fact that many critics of transgenics also oppose the irradiation of foods to kill microorganisms (a technique that has been used for more than forty years). Starting with a blank slate of public opinion on plant breeding, it would be far easier to frighten people about chemical and radiation breeding than about the insertion of a single gene plus a promoter and a marker. The promoter is simply a DNA sequence that allows the gene to be expressed, whereas current techniques require the use of marker genes.

Conclusion

The process and result of genetic modification have been subject to close scrutiny by some of the world's best scientists. The plants and the foods derived from them are extensively tested to assure consumers that these products are safe for the environment and for humans. In a joint report issued in July 2000 the National Academies of Brazil, China, India, Mexico, the United States, the United Kingdom, and the Third World Academy of Sciences concluded: "It is critical that the potential benefits of GM technology become available to developing countries." They also concluded that "steps must be taken to meet the urgent need for sustainable practices in world agriculture if the demands of an expanding world population are to be met without destroying the environment or natural resource base. In particular, GM technology coupled with important developments in other areas should be used to increase the production of main food staples, improve the efficiency of production, reduce the environmental impact of agriculture and provide access to food for small scale farmers" (Royal Society 2000).

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SEE ALSO *Agricultural Ethics; Biotech Ethics; Environmental Ethics; Food Science and Technology; International Relations; Nutrition and Science; Organic Foods*

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GENETIC COUNSELING

Genetic counseling is an educational service that aims to help people become informed and responsible consumers of genetic tests and to cope with the results. With nondirectiveness as a basic rule and autonomous decision making its goal, genetic counseling exemplifies a shift of the professional-client relationship from *doctor knows best* to *patient decides best*.

There is a widespread consensus in advanced scientific and technological societies that in order to guarantee a client's informed choice any genetic test, whether prenatal (by amniocentesis or chorion villus sampling) or adult (for example, for hereditary breast cancer), should be prepared for and followed by genetic counseling. Prior to testing, counselors determine a risk profile by examining a client's medical history and family tree for potential genetic risks. The risk profile determines an array of test options with their risks, potential results, and possible actions, all of which are discussed with the client. After genetic testing, a counselor explains the significance of the test result and reviews treatment options. For example, if a prenatal test result shows a fetal chromosomal aberration, the counselor describes the average development of the fetal population in which the unborn child is placed by its cytological anomaly and offers the possibility of terminating the pregnancy. Both before and after testing, the counselor emphasizes that any decision is the client's.

History

The first *hereditary counseling clinics* opened in Germany and Denmark in the 1930s, and in Britain and the United States in the 1940s. Their explicit goal was to improve the population gene pool by avoiding the birth of children probably affected by illnesses or handicaps. For geneticists of the time, all but a few sympathizing with eugenic ideas, giving *marriage advice* was an instrument for breeding a better society. After World War II, when Nazi Germany brought eugenics into public discredit, geneticists shifted their focus from public to individual prevention without losing track of its effects on the population's quality of health.