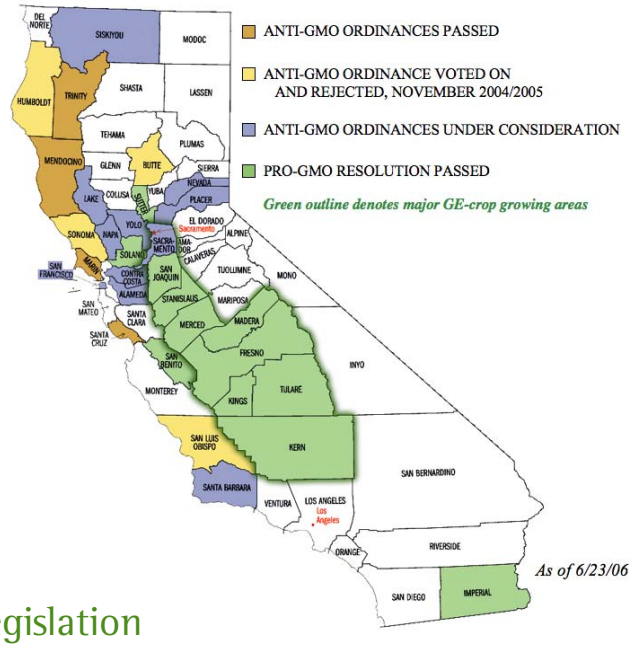
As with other technologies developed in the past, like the domestication of plants and animals, agricultural mechanization, chemical fertilizers, pesticides, these new genetic tools bring questions about risks and benefits. While few, if any, activities in today's technologically complex world involve zero risk, people look to minimize human and environmental risk. We must be educated about these technologies and participate in informed debate about their future.



GE Legislation

In California, a number of county initiatives - either ordinances or resolutions - have focused on whether or not genetically engineered organisms (GMOs) can be grown and propagated. Mendocino County was the first county in California and in the U.S. (March 2004) where voters chose to pass legislation to limit planting GMOs. Fresno County was the first to pass a pro-GMO resolution (February 2004) in which the county claimed the right to plant GE crops. For more information on California County GMO ordinances and resolutions, visit the Resources section at **http://ucbiotech.org**.

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The What & How of Plant Biotechnology

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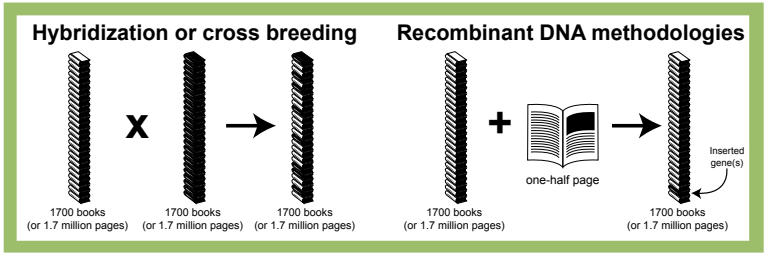
Nearly all food we eat today has been modified by human involvement. When individuals decided to stay in one place rather than move to new sources of food, they began choosing the plants that would give rise to the next generation. For example, they crossed one plant with higher yields with another plant that had increased disease resistance. They screened through the offspring for plants that were both better yielding and more disease resistant. Virtually every plant in today's market was modified in this way and many look little like their ancient relatives.

What is going on when we cross two plants?

Living things are made up of cells and the genetic information in a cell, the DNA, is like a set of recipe cards determining what characteristics a plant has - yellow or red fruit? Resistant or not to a particular pest? If the chemical units in that set of recipes, or the genome, for a wheat cell is represented by alphabetic letters, it would take 1700 books, each of 1000 pages, to contain the information. So, what happens when we exchange information between one 20-story building and another? Genetic rules state you can only end up with one 20-story building. So some of the "recipes" from each parent are kept, giving you a plant with new characteristics. Historically, the breeder who brings the two sets of information together is an observer with little direct control over which "recipes" are retained.



New molecular or recombinant DNA methods, also called biotechnology or genetic engineering, allow the breeder to modify plants in a different way. In this case, the “molecular breeder” can look at the recipes from any living organism, cut it out with chemical scissors and insert it back into the same organism or a different one.

Perhaps the easiest way to understand how these two methods are both similar to each other and different is to look at an example that contrasts the two. Let’s look at two different ways to increase the sugar content of the commercial tomato. This work, carried out at UC Davis was based on the fact that some wild tomato varieties, although quit different looking, have higher sugar content.

In the first approach researchers crossed two varieties using classical methods to get a tomato with higher sugar content, but without the undesirable characteristics of the wild tomato, e.g., smaller size, bitter taste, lower yield. After years of backcrossing to the commercial tomato, they got a higher sugar tomato. In the analogy, they took two stacks of 1700 books, mixed it, and ended up with a final stack of 1700 books with mostly recipes from the commercial tomato, but about 100-200 pages from the wild species. In that 200 pages was information for higher sugar, but also for other traits, like lower fertility, something they didn’t want! This happened because they couldn't "read" the information in the 100-200 pages.

In the second approach, researchers looked at the "recipes" for the tomato fruit and found one responsible for sugar breakdown. This recipe or gene, equivalent to a half-page of information in the analogy, was “removed” by genetic engineering and this slowed sugar breakdown to make the tomato sweeter. In this approach they changed only a half page of information in the 1.7 million page series and they had “read” it so no unanticipated consequences occurred.

In both approaches the genetic exchange utilizes the same machinery; in one case it is accomplished inside the cell, in the other case in the laboratory. In this sense genetic engineering is an extension of classical breeding. But, there are some significant differences between the two methods. First, molecular methods permit precise manipulation of single pieces of genetic material, whereas with classical breeding thousands of genes are exchanged and rearranged. Second, with genetic engineering it is possible to control precisely where and when the new product is made, so sweetness can be directed to the fruit, and not in the leaves or roots. Lastly, and perhaps most importantly to some people, the source of the recipe can be any living organism; it need not be closely related, as is the case with classical methods. This is because all “recipe books” are written in the same language.

How is this done? A part of a plant, like a leaf or a seed, is removed and a gene made up of DNA is introduced into a small number of cells in that tissue. The introduction can be done either by biological or physical methods. The biological method uses a bacterium, *Agrobacterium*, a natural inhabitant of the soil, which can infect plant cells and insert its DNA into the plant’s genetic material. Scientists learned how to put other genes into the inserted DNA and then let *Agrobacterium* do the work of stably introducing the new gene. Another method involves using microscopic, DNA-coated “bullets”, propelled at high speeds that end up inside the cell where the DNA comes off and becomes an inherited part of the genetic information of the plant.

Once DNA is introduced, the researcher multiplies the cells, but the researcher has to find out which cells have the new DNA. This can be done through the introduction of a gene that gives a selective advantage to the engineered cell, e.g. an herbicide- or antibiotic-resistance gene or a gene that allows cells to grow under nutritional conditions the non-engineered cell cannot. The next challenge is to “coax” the cells to reform a plant, through manipulating the hormones in the growth medium. Once this is done, you have a plant, each cell of which contains the new gene.

What else can be done with these molecular tools? In marker assisted selection, the tools are used to speed up breeding by providing molecular “road” maps that tell the breeder what genetic information has been kept in the offspring. Other molecular tools are used to detect diseases in the field at an early stage to help identify pests early and reduce pesticide use.

Introducing new genes can involve using information from the same plant or a different organism, like a bacterium. Some such products have already been commercialized, BollGard cotton, Roundup Ready soybean and canola and YieldGard corn. Other products, still in development in university and private laboratories, include plants with increased pest resistance, improved yield, better drought and salt tolerance, reduced antinutrients like allergens, increased antioxidants and micronutrients like folic acid and iron, and plants that serve as alternative sources of industrial oils and fuels and can remediate metal and organic pollutants from soils and water.