The What & How of Plant Modification

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When people decided to stay in one place rather than moving to find food, they began choosing plants that had desirable traits and crossed them. And nearly all food we eat today has been modified in this way by humans. For example, one plant with higher yield can be crossed with another that resists insects. The offspring can then be screened for plants that yield more and are insect-resistant. Virtually every food in the market today has been modified in this way and looks little like its ancient relatives.

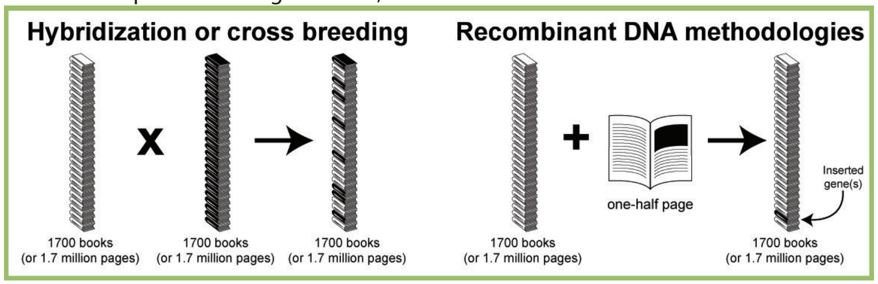
What happens when you cross two plants?

Living things are made up of cells. The genetic information in a cell, the DNA, is like a set of recipes, called genes, that determines what traits a plant has – like whether it has yellow or red fruit, whether it is resistant or not to a particular pest? The DNA is made of chemical units and, if the chemical units in, for example, a wheat cell are represented by alphabetic letters, it would take 1.7M pages, to contain all of that information.

What happens when two wheat plants are crossed, each with 1.7M pages? Genetic rules state that you end up with only 1.7M pages, not 3.4M. About half of the "pages" come from one parent, half from the other (see below). And the new plants end up with a random mixture of traits. The person making the cross, the breeder, has little control over which "recipes" are lost and which are kept. Methods using recombinant DNA, also called biotechnology or genetic engineering, allow breeders to modify plants differently. The "molecular breeder" studies recipes in any organism, equivalent to a half page of information, cuts out a specific recipe with chemical scissors and pastes it into the same organism or a different one.

The two methods of classical and molecular breeding share some similarities and some important differences. In both cases the tools used for cutting and pasting are the same except that the process during classical breeding takes place in the cell while in molecular breeding it occurs in the laboratory. In this sense genetic engineering is similar to classical breeding.

But, there are noticeable 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 the new trait can be targeted to the leaves, the roots, or the seeds, while it is difficult, or sometimes even impossible to do this through classical breeding. Lastly, and perhaps most importantly to



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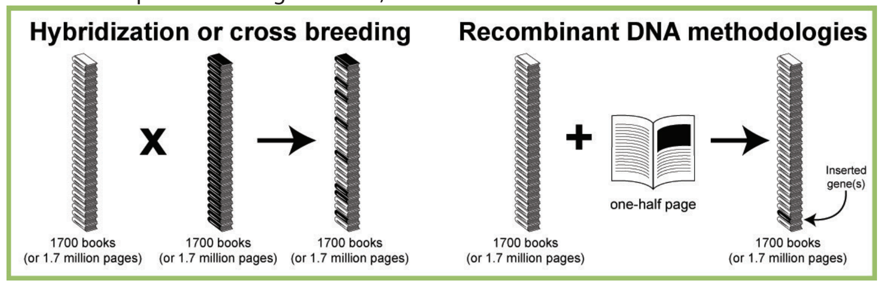

some people, the source of the genetic material can be any living thing. It does not have to be closely related, as is the case with classical methods. This is because all "recipe books" are written in the same language.

How is genetic engineering done? A part of a plant, like a leaf or a seed, is removed and a gene of interest is introduced into a small number of cells in that tissue either by biological or physical means. The biological method uses a naturally occurring bacterium, Agrobacterium, which can infect plant cells and insert its DNA into the plant's genetic material. To use this method to introduce a new trait, a gene of interest is inserted into the Agrobacterium DNA and then the bacterium is left to do the work of stably introducing the new gene. Another method involves using microscopic, DNA-coated "bullets", which are shot at high speeds into the cell where the DNA comes off and inserts into the plant's DNA.

Once the DNA is in the cell, the challenge is to identify which cells received the DNA. This can be done by introducing with your gene another gene that gives a selective advantage to the engineered cell, like the ability to use an unusual sugar or resistance to an antibiotic. The cells are then coaxed to reform a plant, first the leaves and then the roots, through manipulating the plant hormones in the growth medium. Then you have a plant, each cell of which contains the new genes.

What else can be done with these molecular tools? In marker assisted selection (MAS), 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. So if you can find a compatible relative that has the trait you want, you can cross the two plants and use MAS to introduce the desired trait. But this approach won't work if you can't find the trait in a compatible relative.

With genetic engineering you can use genes from the same plant, a different plant or even a different organism, like a bacterium. Some such products have already been commercialized, i.e., insect-resistant cotton or herbicide-tolerant soybean or canola. Other approaches are in development in university and private laboratories and they include plants with increased yields, better drought and salt tolerance, reduced antinutrients like allergens, and increased antioxidants and micronutrients like folic acid and iron. Most recently plants and algae are being created that can make alternative sources of industrial oils and fuels.

As with other technologies developed in the past, like the domestication of plants and animals, agricultural mechanization, chemical fertilizers and 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.

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