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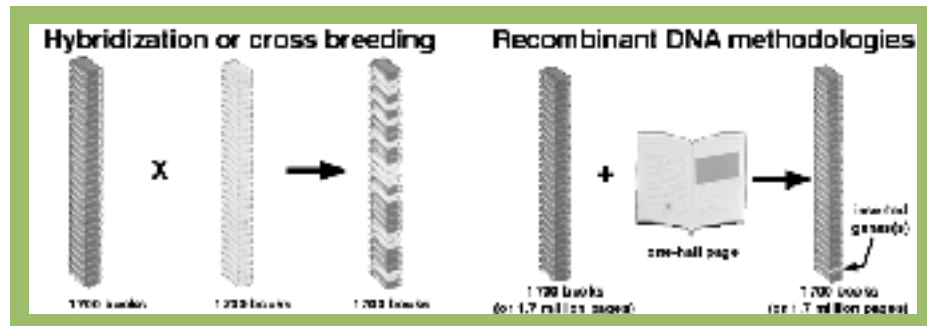
The What & How of Plant Biotechnology

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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 became involved in choosing the plants that 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 of that cross for plants that both yielded better and were more disease resistant. Virtually every plant in today’s market has been modified by such a process, and many look little like their ancient relatives.

What is going on when we cross two plants?

The genetic information in a cell is the set of recipe cards that determines what characteristics a plant has - does it have yellow or red fruit or is it resistant or not to a particular pest. If the chemical units in that recipe, or genome, of a wheat cell, for example, were represented by alphabetic letters, it would take 1700 books, each of 1000 pages, to contain the information. If we stacked those books on top of one another, they would be as high as a 20-story building! So, what happens when we exchange information between one 20-story building and another? Genetic rules state that you can only end up with one 20-story building. So some of the “volumes” are retained from each parent, giving you a wheat plant with new characteristics. In this situation, the breeder is an observer and has no direct control over which “volumes” are retained.



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New molecular or recombinant DNA methodologies, also called biotechnology or genetic engineering, allow the breeder to modify plants in different ways. Perhaps the easiest way to explain the differences and similarities of the two methods is to share an example that contrasts the two. The goal of the work, done at UC Davis, was to increase the sugar content of the commercial tomato in order to enhance its flavor. It is based on the fact that some wild tomato varieties, although they look little like our domesticated tomato, have a higher sugar content than today's varieties.

Researchers first crossed the two varieties using classical breeding techniques, trying to achieve a higher sugar content, but leaving behind the undesirable characteristics of the wild tomato, e.g., smaller size, bitter taste, lower yield. After many years of backcrossing to the commercial tomato, they got a higher sugar tomato. In terms of the analogy, they took two stacks of 1700 books, the content of which was mixed during genetic exchange, and ended up with a final stack of books that contained mostly information from the commercial tomato, but about 100-200 pages from the wild species. In that 200 pages was the information for higher sugar content, but also for lower fertility, something they didn't want. This happened because they didn't know exactly what information was in the 200 pages from the wild species; they couldn't "read" it.

In the second approach to increasing sugar content, researchers looked at the "recipe" for the tomato fruit and found a piece of genetic information responsible for sugar breakdown. This piece of information, a gene, is equivalent to a half-page of information in the analogy. If this were removed from the tomato fruit, they reasoned, sugar breakdown would be slowed and the tomato would be sweeter. Using genetic engineering, they eliminated the degrading enzyme and created a sweeter tomato. In this approach they only changed a half page of information in the 1.7 million page series and they had "read" it. Because of this, there were no unanticipated consequences of this change.

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 the genetic material; only a single or a few genes are introduced at one time, rather than the thousands of genes in the classical breeding approach. Second, the source of the information can be any living organism; it need not be closely related, as is the case with classical methods. Lastly, with genetic engineering it is possible to control precisely where and when the new product will be made. It is possible, for example, to have the sweetness characteristic in the fruit, not in the leaves or roots.



How then are these genetic exchanges accomplished? The creation of genetically engineered plants depends on a unique characteristic of plants that makes it possible to take cells from any part of a plant and, with appropriate "coaxing," make them undergo sustained division and ultimately give rise to an entire plant. Why is this a necessary part of the process? If you can introduce a new gene into a single plant cell and identify which one it is, that single cell can give rise to an entire plant, each cell of which contains the information, the new DNA.



Technically how is this done? A part of a plant is removed, e.g., leaf, stem, seed, and then DNA is introduced into a small subset of the cells in that plant tissue. The introduction can be done either biologically or physically. The biological method involves the use of a bacterium known as Agrobacterium, which naturally infects plant cells and can, as a natural consequence of its infection, insert DNA into the plant's genetic material. Scientists learned how to put genes of interest into the inserted DNA, thereby having a method to stably introduce a new gene. Another method of DNA introduction involves microscopic, DNA-coated "bullets" propelled at high speeds, which ultimately end up inside the cell, where the DNA comes off the "bullets" and becomes a heritable part of the plant.



Once DNA is introduced, the geneticist propagates the cells. During that growth period it is necessary to identify cells that have stably maintained the new information. This can be done through the introduction of genetic information that confers a selective advantage on the engineered cell, e.g. an herbicide- or antibiotic-resistance gene or a gene that allows cells to grow under nutritional conditions that the non-engineered cell cannot. The next challenge is to "coax" the cells to reform a plant, through the manipulation of hormones and other components of the growth medium. Depending on the plant species, this can be the most difficult part of the processes. However, once accomplished, you have a plant, each cell of which contains the new information.



What can be done with these technologies? Some applications utilize the molecular tools but don't involve changing the genetic makeup of the plant. In one application, the tools are used to speed up the process of breeding by providing molecular "road" maps that tell the breeder what parts of the genome have been kept in the offspring. Other molecular tools are used to detect diseases in farmer's fields at an early stage to help control pest infestation and reduce pesticide use.



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Other uses of the technology involve the actual introduction of information into the plant, some from the plant itself and some from other sources. Some of these products have already entered the marketplace, e.g., the NewLeaf potato, BollGard cotton, Roundup Ready soybean, and YieldGard corn. Other products are only in the very early stages of development, many in university laboratories. These include plants with the following characteristics:

- Increased pest resistance to fungal, bacterial, viral and insect pests,
- Improved agronomic characteristics, such as increased yield and a heightened ability to utilize fertilizers and withstand stresses,
- Better post-harvest/processing characteristics, like slow- or no- ripening fruits and vegetables, and higher solids tomatoes,
- Reduction of antinutrients, such as removal of glycoalkaloids or allergens,
- Improved nutritional characteristics, e.g. enrichment for antioxidants and micronutrients, folic acid, iron,
- Pharmaceutical benefit, e.g. plants that vaccinate or prevent/treat human and animal disease,
- Provision of alternative sources of industrial oils, fuels, and plastics, and
- Remediation capability for metal and organic pollutants from soils and water.

As with other technologies developed in the past, e.g. 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, individuals are looking to minimize human and environmental risk. We must be educated about these technologies and their uses and be informed participants in the dialogue about how best to utilize them.

For more information please visit

<http://ucbiotech.org>

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