THE NITTY GRITTY OF GENETIC MODIFICATION

HOW ARE ORGANISMS GENETICALLY MODIFIED?

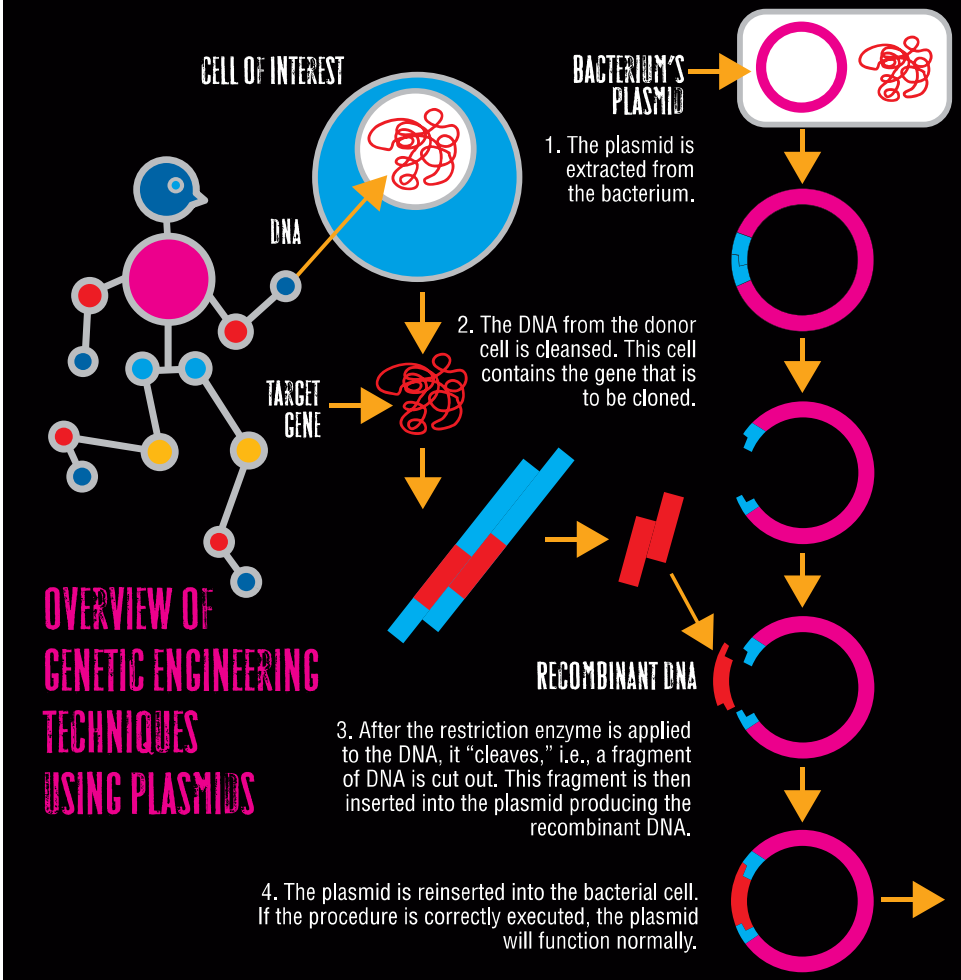
Want a plant that fends off insects as easily as water rolls off a waxed car? Need a mouse with sickle cell anemia so that you can research treatments? Changing the genetic structure of plants and animals to alter their processes is no longer the stuff of science fiction. It has become a fairly routine laboratory procedure, made possible by the unique structure of deoxyribonucleic acid, DNA.

You know that DNA is a long molecule identified by a sequence of four chemical bases (adenine, guanine, cytosine, and thymine). Genes are segments of the DNA that tell cells to produce specific proteins such as enzymes essential for plant growth and development. Some of these enzymes jump-start biochemical reactions essential to genetic modification.

DNA has two characteristics that genetic engineers find useful. First, its commands to a cell are followed the same way regardless of what organism the cell is in, so DNA can be inserted from one organism to another. For example, a gene that produces a protein that kills caterpillars can be transferred from a bacterium to a corn plant and the corn plant's cells will still make that protein, protecting the plant from caterpillar damage.

Second, enzymes can be used to "cut and paste" pieces of DNA. Some enzymes can cut DNA at specific points, while others can join the two ends of severed DNA that match.

Put all these facts together, and bingo! you can modify genes. Scientists have developed techniques for inserting DNA into plants, animals, and microbes.



OVERVIEW OF GENETIC ENGINEERING TECHNIQUES USING PLASMIDS

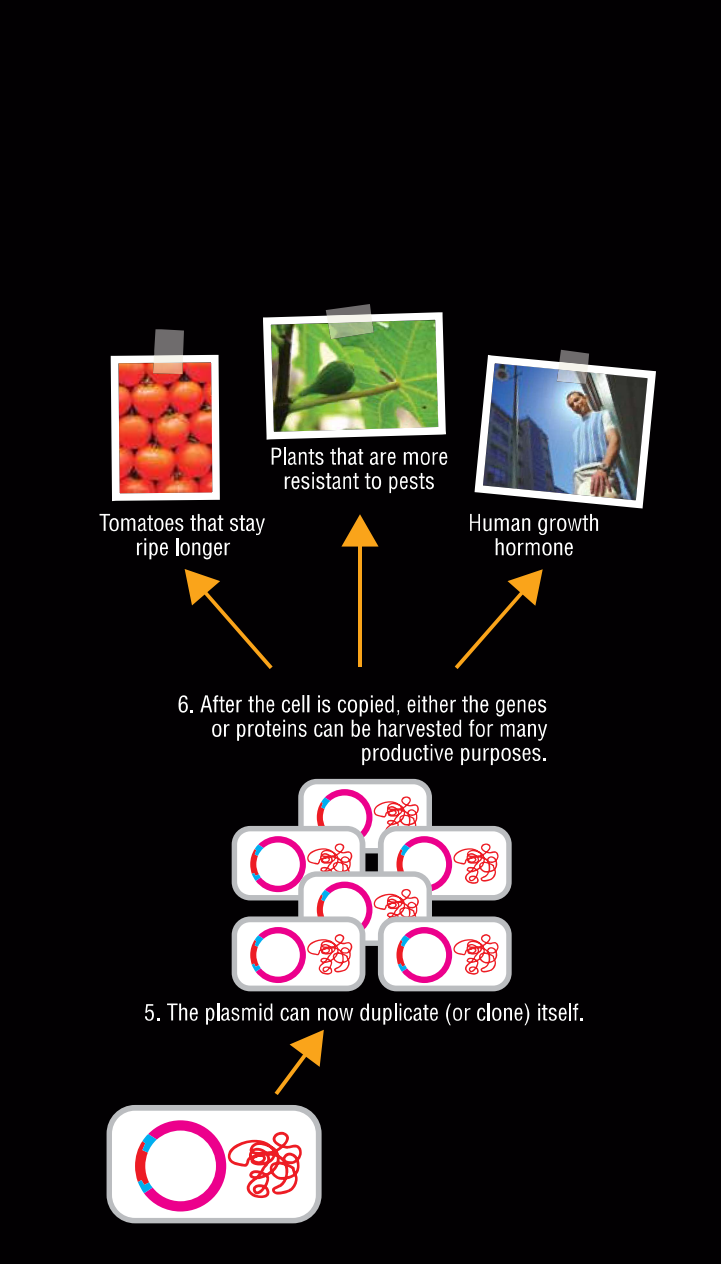
IN PLANTS

How do scientists transfer genes from one organism to another? In plants, two methods are commonly used—*Agrobacterium* and the "gene gun."

AGROBACTERIUM METHOD

Agrobacterium tumefaciens, a bacterium that naturally lives in the soil, infects plants through a wound that causes a tumor to form. This tumor-producing property enables *A. tumefaciens* to transfer part of its DNA to the plant cell. This DNA integrates into the plant's genome, causing tumors and related changes in plant metabolism. This unique trait has made it possible for this bacterium to be used as a tool in plant breeding. Any desired genes, such as insect toxic genes or herbicide-resistant genes, can be engineered into the bacterial DNA and then placed into the plant genome. The use of *Agrobacterium* allows entirely new (nonplant) genes to be engineered into crops.

Most of the genes that cause the tumor are not on *Agrobacterium's* chromosome, but in a separate ring of DNA in the cell called the *Ti* (Tumor-inducing) plasmid. To be more specific, only part of this plasmid, the T-DNA (Transfer DNA), enters another cell to cause a tumor. In plant engineering, selected genes are put into the T-DNA. The plasmid transfers the "new DNA" to be incorporated into the plant genome. Cells with the new DNA incorporated



are called *transformed* and the transformed cells are called *transgenic.* The transgenic plant cells are then placed in a special culture to multiply and develop into embryos that mature into complete plants.

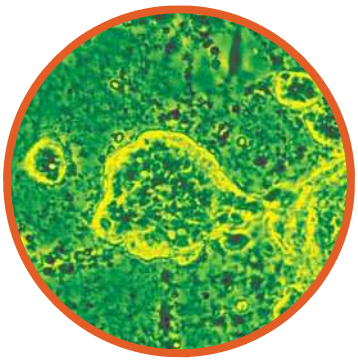
Recently, scientists have learned how to modify other types of bacteria, giving them the capacity to serve as gene vectors. This approach is called the open-source method. These bacteria will be available, for free, to anyone who wants to use them, making it easier for scientists in public institutions all over the world to develop improved crops using biotechnology.

GENE GUN METHOD

Sometimes referred to as *biolistics,* this approach uses a gun-like device to bombard an organism with DNA. Here's how it works:

- Tiny particles of gold or tungsten are coated with DNA or RNA and placed on a plastic plug. The "bullet" is placed in a device called a gene gun.
- The DNA-coated particles are propelled out of the gun, and while the bullet is stopped short of the target tissue, the momentum of the traveling DNA sends it into the target plant cells. The DNA enters the cells' cytoplasm and makes its way to the nucleus, where it becomes part of the DNA there.

This method is also being studied as a way to target diseases, such as cancer in humans.



A stem cell can carry new DNA into animals.

IN ANIMALS

Just as ways to insert genes into plants had to be developed, so did techniques for animals. Like plants, before a gene can be inserted into an animal cell, it has to become part of a transgene, a section of genetic material containing the desired gene plus some extra DNA that allows the gene to be expressed correctly and at the right time. Three methods for introducing the transgene are microinjection (inserting the new DNA directly into fertilized eggs), embryonic stem cell transfer, and retroviral vectors.

All methods have the same first step—combining DNA in the laboratory, creating the specific gene desired. In microinjection, the new gene is inserted directly into a fertilized egg and then implanted into a female animal's uterus. In method two, however, embryonic stem cells are grown in the laboratory, mixed with the new gene, inserted into a fertilized egg, and then implanted into a female. With retroviral vectors, certain viruses can be used to carry the selected gene into embryonic cells. The gene is still inserted randomly into the genome as with microinjection. As the technology continues to be refined, much more is possible.

—Marilyn Fenichel

STANLEY N. COHEN AND HERBERT W. BOYER PIONEERED RECOMBINANT DNA TECHNIQUES THAT LED TO SCIENTISTS BEING ABLE TO TRANSFER ONE GENE FROM ONE ORGANISM TO ANOTHER. GENETIC ENGINEERING DEBUTED IN 1973, THE SAME YEAR THE CD WAS INVENTED.