DNA Daredevils

From building better crops to fighting disease, genetic engineers are changing our world

Genes are the instructions to make proteins, which are responsible for almost all of the processes that keep organisms alive. In 1973, biochemists Stanley Cohen of Stanford University and Herbert Boyer of the University of California at San Francisco first transferred genes for antibiotic resistance into E. coli bacteria. These early pioneers of genetic engineering may not have imagined how influential their work would become. These days, genetic engineering techniques are used, for example, to insert genes from other organisms into bacteria, which then churn out proteins that produce hepatitis-B vaccine and insulin for diabetics. Botanists genetically modify crops to boost hardiness and nutritional value.

Yet geneticists do more than bestow organisms with new characteristics. They also manipulate DNA to study the role of individual genes. Scientists add, delete, or modify genes, thus altering the corresponding proteins' structure or levels in the cell and revealing the genes' role.

Researchers have tinkered with the DNA of organisms as varied as mammals, birds, fish, insects, worms, plants, fungi and bacteria. These studies have given scientists invaluable insights into how the human body functions and why disease arises. Which genes predispose us to breast cancer and which protect against heart disease? Which genes allow a bacteria or virus to cause illness? Identifying these genes can provide targets for new antibiotic and antiviral drugs. Further, gene therapy could someday allow us to cure diseases like cystic fibrosis and some cancers by replacing defective genes. Genetically engineered microbes could produce new biodegradable polymers or clean up radioactive wastes. Although we've sequenced the complete genomes of many organisms—humans included—we still don't understand what all those genes do. As our quest for knowledge continues, the role of genetic engineering will only expand.

Bacterial DNA is injected into eggs of the Indian meal moth, an agricultural pest.

SPL/FOCI

Four Ways to Manipulate Genes

Amplify
a characteristic

PURPOSE: To learn more about a gene's role in an organism

SOLUTION: Manipulate or add an extra copy of the gene to increase its activity.

CASE STUDIES: Overexpression of a gene responsible for a cell's ability to respond to a protein called epidermal growth factor is associated with most cancers. This finding has led to the development of anticancer drugs that target the expression of this gene.

Delete
a characteristic

PURPOSE: To learn more about a gene's role in an organism, this time by seeing what happens when the gene is removed

SOLUTION: Scientists remove or replace the normal functioning version of the gene.

CASE STUDIES: Deleting certain genes in mice has shown how their absence affects disease. Knocking out genes like PINK1 or DJ-1, for example, can lead to Parkinson's symptoms in mice, providing an animal model to study the disease.

Modify
a characteristic

PURPOSE: To identify the specific sequence of DNA that is responsible for a gene's function

SOLUTION: A mutated gene is inserted into an organism. The gene produces a modified protein.

CASE STUDIES: Modified genes may explain how enzymes bind to other molecules. Angiotensin-converting enzyme, for example, plays a role in heart function and diabetes. Protein sequences allow the enzyme to bind to ions, which helps to regulate its activity.

Map
a characteristic

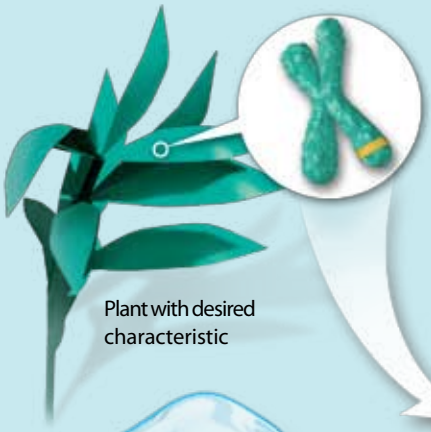
PURPOSE: To understand the activity of a gene and its protein

SOLUTION: A "marked" gene is transferred into an organism's cells.

CASE STUDIES: Proteins of marked BRCA1 genes, whose mutation can increase the risk of breast and ovarian cancer, were found in the cells' mitochondria. BRCA1's presence there may be important for its function in suppressing tumors, because cancer is often associated with mutated mitochondrial DNA.

Using Bacteria to Engineer Plants

Plant geneticists often use a bacterium called Agrobacterium tumefaciens to transfer a desirable characteristic from one species to another. Here's how:

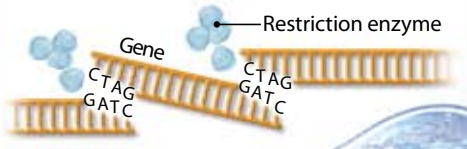


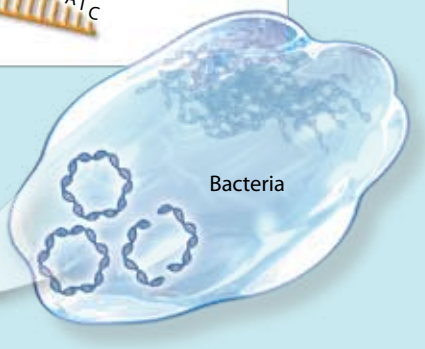
Plant with desired characteristic

1. Remove a desirable gene from a plant

To transfer a characteristic, such as resistance to drought, scientists must isolate that gene from the plant.

Proteins called restriction enzymes recognize and cut certain DNA sequences in the plant's genome. The enzymes are picked so that they cut specific sites on either side of the desired gene.

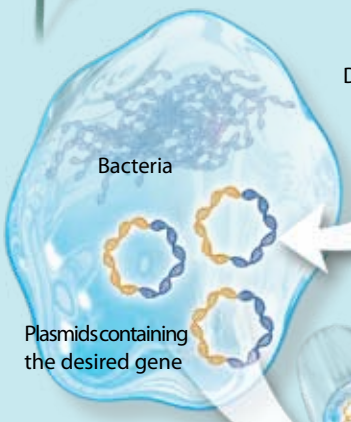




Bacteria

Desired gene

Cut plasmid



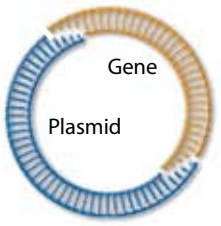
Bacteria

Plasmids containing the desired gene

2. Place the gene in a bacterial plasmid

To transfer genes into plant cells, DNA molecules called plasmids are extracted from the A. tumefaciens bacteria.

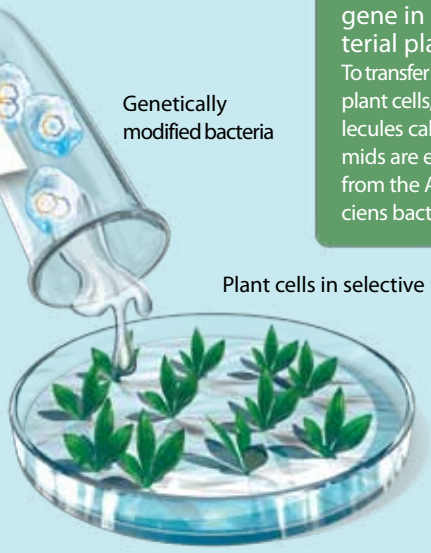
Researchers cut the plasmid at a specific place using restriction enzymes and use another enzyme to join the gene and the plasmid.



Genetically modified bacteria

3. Reintroduce the plasmid

The plasmid containing the new gene is reintroduced into bacteria. The plant is then exposed to the engineered bacteria.

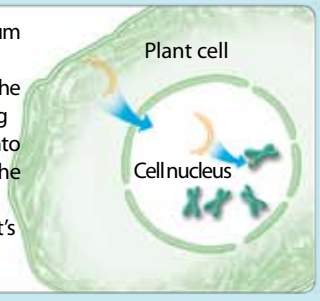


Plant cells in selective medium

4. Transfer the gene into a different plant species

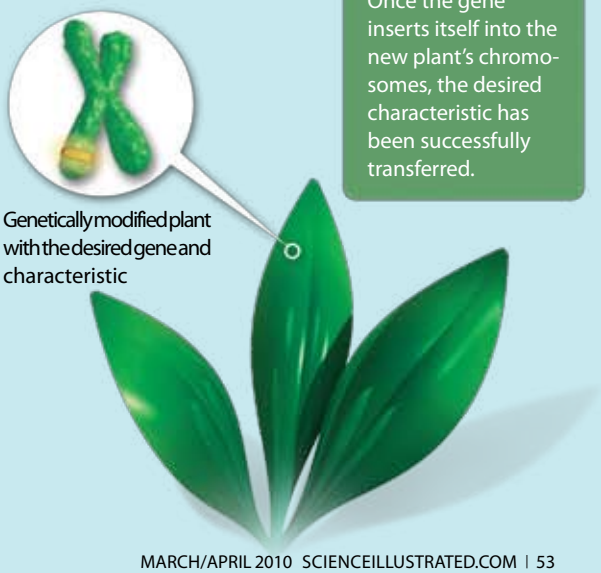
The bacteria transfer DNA from their plasmids into the plant cells around them.

Agrobacterium can directly transfer the part of the plasmid containing the desired gene into plant cells, where the DNA can insert itself into the plant's chromosomes.



5. Observe the new characteristic

Once the gene inserts itself into the new plant's chromosomes, the desired characteristic has been successfully transferred.



Genetically modified plant with the desired gene and characteristic

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