Heredity & Technology

Biotechnology *is a branch of science that uses living organisms to manufacture food, drugs, or other products.*

History of Genetic Engineering

Rudimentary biotechnology has been around for thousands of years. Whenever yeast is used to bake bread or whenever grapes, malt, or milk is fermented to make wine, beer, or cheese, someone is using biotechnology.

Charles Darwin

Gregor Mendel

Another popular biotechnological technique that is frequently used by society is **selective breeding**. Using this technique, farmers or ranchers select certain crops or animals to breed based off of desirable traits (e.g. the strongest bull, the fastest horse, the most virus-resistant corn, the largest tomato, etc.). Although this technique has been around for centuries, Charles Darwin's studies on natural selection and Gregor Mendel's studies in genetics helped to explain the scientific mechanism behind this popular technique.

Current Trends in Biotechnology

Recent biotechnology methods, such as genetic engineering, gene therapy, and genetic counseling, require more advanced technology and a more advanced prior knowledge of natural systems. Current biotechnology methods include genetic modification (also known as genetic engineering, gene splicing, gene therapy, transgenics, or recombinant DNA technology), cloning, and DNA fingerprinting.

All genetic modification techniques involve inserting, deleting, or substituting DNA segments into an organism's natural genomic material. Typically these modifications are made in order to somehow enhance the organism. For example, crops, such as tomatoes, corn, and cotton, or animals, such as cattle and sheep, can be genetically modified to be more resistant to diseases that often infect them. Genetic modification techniques require extensive knowledge of the organism's genome, however, because genes cannot be safely manipulated if the traits that they express are unknown.

Even complete understanding of gene functionality cannot prevent problems from occurring. There are still risks involved with the introduction of genetically modified organisms. Engineered crops pose the danger of spreading and reproducing with wild types. In addition, the modifications may not necessarily work. Just as insects can become resistant to chemical pesticides, there is the same risk that they could become resistant to chemicals produced due to the insertion of genes from other organisms.

In 1980, scientists began mapping the human genome. This project was completed in 2003. With the completion of this project comes the hope that genetic manipulation in humans might be able to cure certain genetic disorders. This process of replacing absent or faulty genes is known as gene therapy.

The following video discusses the results of the Human Genome Project, their potential applications, and the possible implications of this knowledge on society.

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Impact of Genomics

*The **Human Genome Project** was a 13-year-long research effort which included scientists from several countries around the world. The scientists working on the Human Genome Project were attempting to identify all of the approximately 20,000-25,000 genes in human DNA and find the sequences of the 3 billion chemical base pairs that make up human DNA. The scientists completed the project in 2003.*

The directors of the Human Genome Project are hoping that the information gained from the project will help other scientists develop new forms of biotechnology. Knowing more about the human genome may help improve technology in the following fields:

- **Molecular medicine** - involves the diagnosis and treatment of different genetic diseases.
- **Microbial genomics** - involves the use of genetically engineered bacteria for bioremediation, pollutant detection, the production of biofuels, and more.
- **Bioarchaeology and anthropology** - involves the study of human evolution and migration.
- **DNA forensics** - involves the use of DNA to help solve crimes, including the use of a DNA fingerprint (the unique pattern of dark bands on photographic film that is made when an individual's

DNA restriction fragments are separated by gel electrophoresis, probed, and then exposed to an X-ray film).

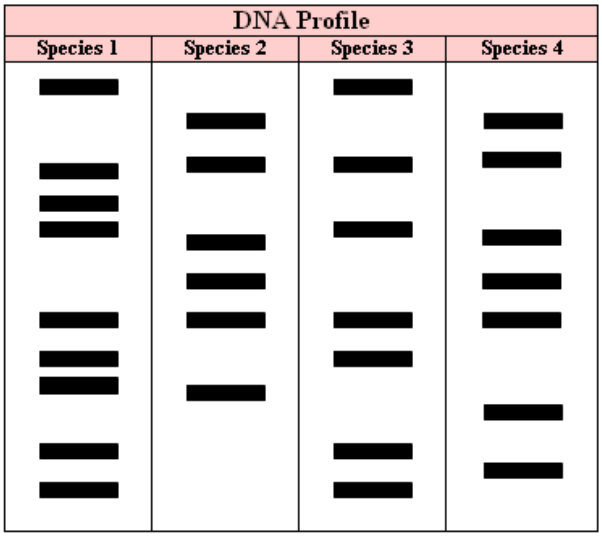
- **Agricultural genetic engineering** - involves the genetic engineering of pest- or drought-resistant crops, healthier farm animals, biopesticides, crops containing life-saving vaccines, and more.

As you can see from the list above, many of the applications of the Human Genome Project involve genetic engineering. Genetic engineering is the process of manipulating genes for practical purposes. Genetic engineering often involves the use of recombinant DNA, which is DNA made from two or more different organisms.

DNA Fingerprinting

*One of the ways scientists judge whether two species or two individuals are related is through the study of the organisms' genetic sequence, or **DNA profile**.*

While each species or individual has its own unique DNA sequence, sequences of related organisms will be more similar than sequences of unrelated organisms.



In this example of a DNA profile, species 2 and species 4 are more closely related to each other than to the other species. This can be determined by comparing the location of the bands in the different samples. The more band locations the organisms have in common, the more likely it is that the organisms are related.

Genetic Engineering

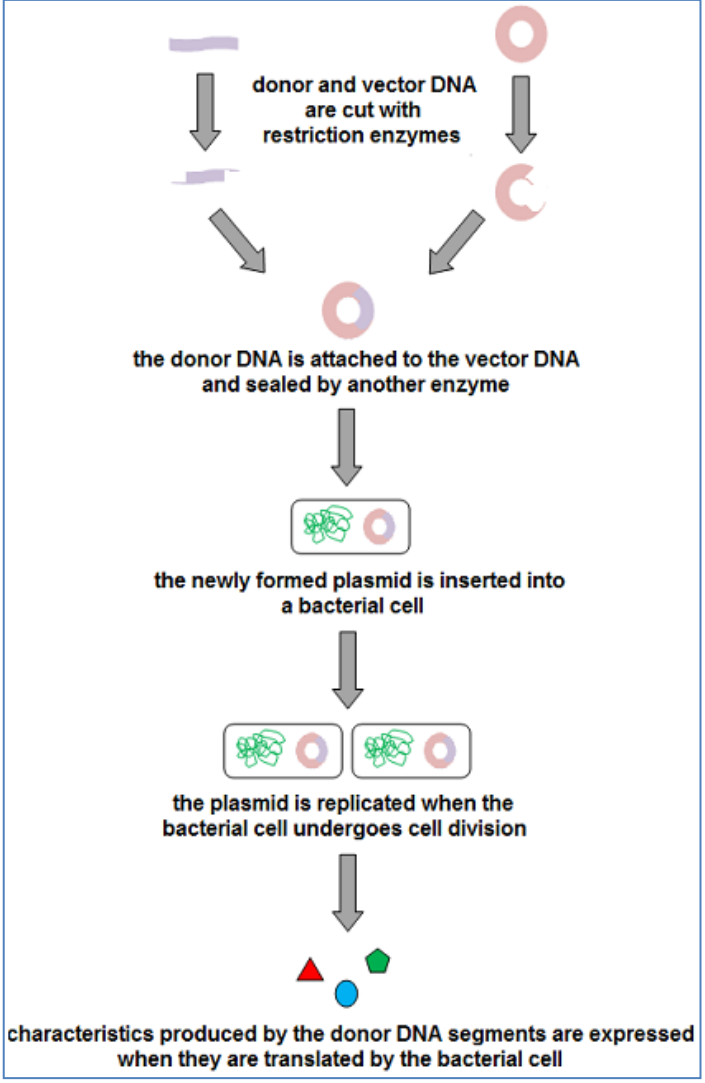
*Through the process of **genetic engineering**, the genetic code of plants, animals, or microorganisms is manipulated to obtain a desired product. Genetic engineering has many practical applications in medicine, agriculture, and biology.*

Potential Applications

Examples of the potential applications of genetic engineering include:

- using bacteria with recombinant DNA to produce medicines, such as insulin;
- inserting functioning genes into the cells of individuals with mutated genes to cure genetic disorders;

- modifying the genetic makeup of certain crops to make them more nutritious or more resistant to bacteria;
- genetically altering fruit to contain vaccines so that they can be administered more cheaply and easily; and,
- using bacteria that have been modified to consume toxins to clean up spilled pollutants in the environment.



The Process

Genetic engineering can be done using **recombinant DNA technology**. Using this technology, different enzymes can be used to cut, copy, and move segments of DNA. Characteristics produced by the segments of DNA can then be expressed when these segments are inserted into new organisms, such as bacteria. The diagram below shows the process of recombinant DNA technology.

Gene Therapy

*The genetic techniques developed have opened the door to a variety of applications. One such application is the ability to alter an individual's genes through **gene therapy**.*

During **gene therapy**, specific gene sequences are inserted into an individual's cells to replace a defective or mutant allele. Scientists have found that the most efficient and effective way to accomplish this is by using viruses to insert the gene sequences into cells. This is possible because all viruses naturally insert their genetic material into their host cells as part of the viruses' replication cycle.

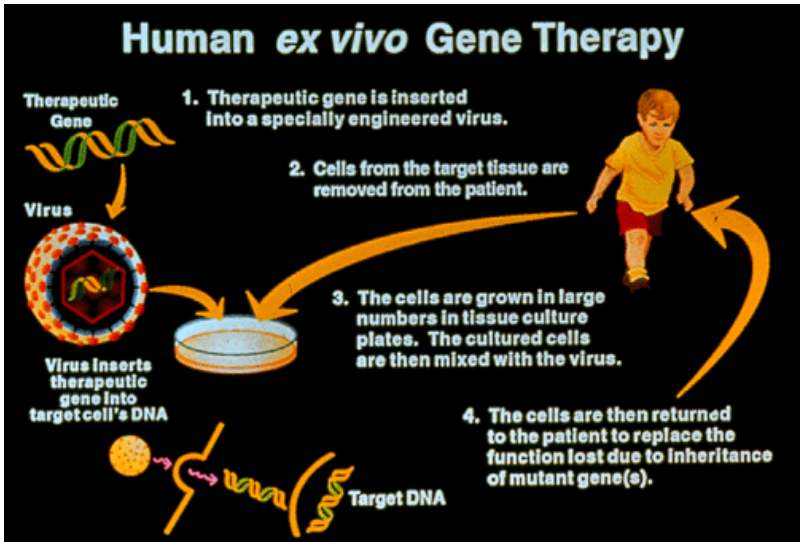


Image courtesy of NIH and the National Human Genome Research Institute.

Gene therapy is currently being used to try to cure genetic disorders, such as sickle cell anemia and cystic fibrosis. During this process, specific DNA sequences are inserted into an individual to try to replace faulty or absent genes so that normal gene expression can occur rather than abnormal gene expression.