Biotechnology

Definition: biotechnology from Dictionary of Virology

Industrial processes requiring the use of biological systems, including genetic engineering, fermentation technology, hybridoma technology, and agricultural technology.

Summary Article: Biotechnology from Encyclopedia of Contemporary American Social Issues

Although biotechnology can be defined broadly to include any technological application that uses a biological system or organism, the term has become synonymous with the use of modern technology to alter the genetic material of organisms. The ability to recombine DNA across species has created significant social controversy over the creation of biohazards, “terminator” genes, genetic pollution, “playing God,” and the ethics of altering the lives and appearance of animals.

Background and Development

Biotechnology may be considered as any technological application that uses biological systems, living organisms, or their derivatives. The term biotechnology covers a broad range of processes and products and can be understood from at least two perspectives. From one perspective, biotechnology (1) is the process of using (bio)organisms to produce goods and services for humans. The use of yeast in the processes of fermentation that make bread and beer and the historical domestication of plants and animals are examples of this kind of biotechnology. From another perspective, biotechnology (2) is the process of using genetic technologies to alter (bio)organisms. This perspective is illustrated by the hybridization of plants, the cloning of sheep, and the creation of genetically engineered food crops. Although both perspectives are debatable endeavors, biotechnology type 2 is inherently more problematic than type 1. Most ethical, moral, and religious criticism of biotechnology focuses on type 2 biotechnology. The United Nations definition, then, focuses on the history and problems associated with type 2 biotechnology.

Biotechnology type 2 began in the late nineteenth century as the rise of the science of genetics established a basis for the systematic and conscious practice of breeding plants and animals. In 1944 Oswald Avery identified DNA as the protein of heredity. In 1953 James Watson and Francis Crick discovered the structure of DNA. Biotechnology blossomed in the late 1960s and early 1970s with the development of recombinant DNA technology and the birth of the biotechnology industry. In 1997 the human genome was mapped and sequenced. Since the 1990s, an increasing number of techniques have been developed for the biotechnological reproduction and transformation of organisms. An examination of controversies associated with biotechnology includes at least the biotechnological modification of microorganisms, of plants, and of animals.

In the early 1970s, researchers across the world began exploring recombinant DNA (rDNA) technology, or the technology of joining DNA from different species. rDNA technology is performed either by a gene-splicing process, wherein DNA from one species is joined and inserted into host

https://search.credoreference.com/content/topic/biotechnology
cells, or by cloning, wherein genes are cloned from one species and inserted into the cells of another.

In 1972 biochemist Paul Berg designed an experiment allowing him to use rDNA technology to insert mutant genetic material from a monkey virus into a laboratory strain of the *E. coli* bacterium. Berg did not, however, complete the final step of his experiment because he and his fellow researchers feared they would create a biohazard. Because the monkey virus was a known carcinogen and the researchers knew that *E. coli* can inhabit the human intestinal tract, they realized their experiment might create a dangerous, cancer-inducing strain of *E. coli*.

Berg and other leading biological researchers feared that, without public debate or regulation, rDNA technology might create new kinds of plagues, alter human evolution, and irreversibly alter the environment. Berg urged other researchers to voluntarily ban the use of rDNA technologies and sent a letter to the president of the National Academy of Science (NAS). The NAS responded by establishing the first Committee on the Recombinant DNA Molecules. In 1974 that committee agreed to the temporary ban on the use of rDNA technologies and decided that the issue required the attention of an international conference. Scientists worldwide were receptive to the voluntary ban and halted their work on rDNA experiments.

In February 1975, Berg and the NAS organized the Asilomar Conference on Recombinant DNA. Lawyers, doctors, and biologists from around the world convened in Monterey, California, to discuss the biohazard and biosafety implications of rDNA technology and to create a set of regulations that would allow the technology to move forward.

This conference provided a meaningful forum for discussing both whether scientists should use rDNA technologies and how to safely contain and control rDNA experiments. The Asilomar participants were able to identify proper safety protocols and containment procedures for some of these experiments, and they also prohibited some experiments, such as Berg's experiment involving cloning of recombinant DNA from pathogenic organisms.

The Asilomar conference resulted in the first set of National Institutes of Health (NIH) guidelines for research involving recombinant DNA. These guidelines are still the primary source of regulation of recombinant DNA research and have been periodically updated by the NIH.

The Asilomar conference also stimulated further controversy involving rDNA technologies. On one side, concerned citizens and public interest groups that had not participated in the conference began to demand a voice in the regulation of recombinant DNA technologies. The city of Cambridge, Massachusetts, exerted its power to control the rDNA research conducted in its universities, creating the Cambridge Biohazards Committee to oversee DNA experiments. The environmental organization Friends of the Earth even brought a lawsuit demanding that the NIH issue an environmental impact statement on rDNA research. On the other side, biological researchers opposed the inclusion of the public in the rDNA discussion. These researchers feared that public participation in the matter might restrict and compromise the freedom of scientific research.

**Ongoing Research and Debate**

Humans have for centuries used selective breeding and hybridization techniques to alter food-producing plants. The introduction of recombinant DNA technologies, however, has allowed
humans to genetically cross plants, animals, and microorganisms into food-producing plants. There are two basic methods for passing genetic traits into plants. First, biologists can infect a plant cell with a plasmid containing the cross-species genes. Second, biologists can shoot microscopic pellets carrying the cross-species genes directly through the cell walls of the plants. In either case, biologists are reliably able to move desirable genes from one plant or animal into a food-producing plant species.

For instance, scientists have already spliced genes from naturally occurring pesticides such as *Bacillus thuringiensis* into corn to create pest-resistant crops and have genetically altered tomatoes to ensure their freshness at supermarkets.

Genetic technologies allow an increase in properties that improve nutrition, improve the capacity to store and ship food products, and increase plants’ ability to resist pests or disease.

In 1994 the U.S. Food and Drug Administration approved the first genetically modified food for sale in the United States. Now genetic modification of food supplies is pervasive, particularly in staple crops such as soy, corn, and wheat. Cross-species gene splicing has, however, created at least two significant controversies.

One controversy arose over the use of “terminator” gene technologies. When biotechnology companies began to produce foods with cross-species genes, they included terminator genes that sterilized the seeds of the plants. This terminator technology served two functions: it kept the plants from reproducing any potential harmful or aberrant effects of the genetic engineering, and it also ensured that farmers who purchased genetically modified plants would need to purchase new seeds from the biotechnology companies each year.

The use of terminator technologies caused an international social debate, especially when biotech companies introduced their genetically modified foods into developing countries. Because farmers in developing countries tend to reseed their crops from a previous year’s harvest, the terminator technology created a new and unexpected yearly production expense. Civil and human rights groups urged banning the introduction of genetically modified crops in developing countries, arguing that any potential nutritional or production benefits offered by the genetically modified foods would be outweighed by the technological mandate to purchase expensive, patented seeds each year. In response to this, Monsanto (the biotechnology company that owns the rights to the terminator gene patents) pledged not to commercialize the terminator technology. Human rights groups continue to work toward implementing legal bans on the use of the technology, however.

Another controversy arose with a concern about genetic pollution. Although biologists are reliably able to splice or physically force gene sequences from one species into another, they are not always able to control the reproduction and spread of the altered plants. This has created serious debate over the introduction of genetically modified food from laboratories into natural ecosystems.

One concern is that the genetic alterations will pass from the food-producing crop to weeds that compete for nutrients and sunlight. One good example occurs with pesticide-resistant crops. Some biotechnology companies have modified crops to resist the application of certain pesticides. This allows farmers to apply pesticide to their fields while the modified crop is growing, thus reducing competition from weeds and attacks by pests. However, biologists cannot always control whether the pesticide-resistant gene will stay confined to the food-producing crop. Sometimes the pesticide-
resistant gene migrates to surrounding plants, thus creating “super weeds” that are immune to the application of pesticides.

Another concern is that the genetic alterations will unintentionally pass from the modified food-producing crop into another natural strain. Here the concern is that the uncontrolled movement of cross-species genetic alterations may alter evolutionary processes and destroy biodiversity. For example, one controversy focuses on whether the introduction of genetically modified corn has led to the cross-pollination of native Mexican strains of maize. There is also a concern about introducing strains of genetically modified potatoes into areas of Peru, where subsistence farmers safeguard many native strains of potatoes.

The final and perhaps most important social concern is the safety and quality of the food produced by genetically altered plants. There has been a general inquiry into the safety of genetically modified foods. Because few tests have been conducted into the safety of these foods or the long-term effects on human health, there is a strong movement, particularly in western European countries, to ban “Frankenfoods.” There has been an even stronger reaction over the labeling and separation of genetically modified foods. Moving genes from one species to another food-producing crop can raise serious allergy and safety concerns. When, for example, one company began splicing desired genes from Brazil nuts into soybeans, it became apparent that the resulting modified soya plant would induce allergic reactions in any person with a nut allergy. However, because food distribution systems, especially in industrialized countries, tend to collectively amass and distribute staple crops, there is no way to tell which foods contain genetically altered plants if no labeling or separating requirement is installed. This raises concerns about the ability to recall products should scientists discover a problem with genetically altered foods.

As with agriculture, humans have long practiced forms of animal biotechnology by domesticating animals and through practices of animal husbandry. However, the use of rDNA technology has allowed humans to clone animals and produce transgenic animals. Scientists now genetically insert genes from cows into chickens to produce more meat per animal, genetically alter research laboratory rats to fit experiments, and genetically modify pigs to grow appropriate valves for use in human heart transplant procedures.

Although all the concerns about plant biotechnology, and particularly the concern about genetic pollution, apply to the genetic manipulation of animals, there are several controversies unique to the application of biotechnology to animals.

The first, and perhaps most fundamental, controversy over the application of biotechnology to animals is the moral reaction against “playing God” with recombinant DNA technologies. Many religious and ethics groups have chastised biologists for violating fundamental limits between species that cannot, without major evolutionary changes, otherwise breed. This has brought a serious debate over whether the biotechnological mixing of species is unnatural or whether it merely demonstrates the arbitrary segregation of our scientific categories of kingdoms and species.

Another controversy unique to applying biotechnology to animals concerns the rights and welfare of genetically modified animals. Genetic technology has, for example, allowed great advances in xenotransplantation (the use of pigs as sources of organs for ailing human beings) and in genetically altering laboratory rats. This enables scientists to “pharm” medical products and
laboratory subjects from genetically altered animals. However, this ability to extract resources from animals comes into direct conflict with a growing awareness of ethical duties toward animals and of animal rights. Although few critiques suggest that these ethical duties require us to abandon the practice of applying biotechnology to animals, they have raised serious questions about how genetic modifications alter the lives of animals and what sorts of safeguards or standards should be employed in animal biotechnology.

See also Genetic Engineering; Genetically Modified Organisms; Stem Cell Research

Further Reading


Sheppard, Celene


https://search.credoreference.com/content/topic/biotechnology
APA

Chicago
https://search.credoreference.com/content/topic/biotechnology

Harvard

MLA