

Lesson 1:
An Overview of Biotechnology

The word “biotechnology” probably brings to mind an image of scientists in a laboratory, but it is much more than pure scientific research. Biotechnology is as old as making wine and as new as gene- splicing. It is applied to crops in the field and livestock in the barn.

Defining Biotechnology

The term “biotechnology” is often regarded as highly technical and scientific. Most members of the general public have heard of biotechnology, but they do not know how to define it. “Bio” refers to living things, and “technology” involves the application of science. Biotechnology can therefore be defined as the application of scientific principles to living things. It involves harnessing the natural biological processes of cells from microorganisms, animals, and plants to develop useful products. This broad definition of biotechnology includes processes such as fermentation and the use of yeast to cause bread to rise. These processes have been used for centuries.

A narrower definition of biotechnology includes only those processes that involve the recombination of genes from living things in a laboratory setting. The recombination of genes involves cutting and relinking a DNA strand. Modern biotechnology dates from the 1970s, when scientists first developed a way to splice genes from the DNA of one organism into the DNA of another organism.

When animals or plants reproduce sexually, DNA is transferred from the two parents to the offspring. This transfer of DNA is a natural process. Selective breeding of animals or plants can be considered biotechnology because a natural biological process is being harnessed to produce a useful product. Modern biotechnology, however, allows a scientist to transfer specific genes from one organism to another. The new organism will have a predetermined trait based on this genetic information.

The Past Role of Biotechnology

Biotechnology has played a vital role in crop production throughout history. One of the earliest examples of biotechnology was the development of fruit tree grafting techniques by the Greeks around 300 B.C. Crop biotechnology was greatly advanced by Gregor Mendel’s experiments with garden peas in 1865 and his discovery of the foundations of genetics. The development of the first hybrid corn plant in 1879 is another example of how biotechnology has affected agriculture. In 1933, fewer than 1 percent of the U.S. corn crop came from hybrid plants, but by 1943, more than 70 percent of the crop was produced with hybrid corn. Crop production was again enhanced by the international development of improved wheat and rice varieties between 1946 and 1965.

Biotechnology has also been important in animal production. Selective breeding of livestock was practiced by people in the Middle East as early as 18,000 B.C. Animal crossbreeding and purebreeding were practiced in Europe as early as 1500 A.D. A procedure for artificial insemination was first developed in Italy in the late eighteenth century.

Biotechnology has also affected the food processing industry. The use of bacteria to make cheese, bread, and alcohol began in Egypt between 4,000 and 2,000 B.C. The food processing industry was boosted by the invention of the modern distillery in the United States in 1830, which optimized the process of fermentation to produce alcohol. In the 1860s, Louis Pasteur discovered that fermentation was carried out by bacteria and confirmed the existence of microorganisms, leading to applications such as the large scale brewing of beer and wine.

Biotechnology: Applications in Agriculture

Emerging Applications of Biotechnology

The modern era of biotechnology began with the first successful recombination of DNA in 1973. This achievement was the first step in the development of genetic engineering. Genetic engineering (also referred to as genetic modification or genetic manipulation) is the alteration of the genetic material of living cells by incorporating different genes to produce organisms with new characteristics.

In the late 1970s, scientists developed the technique of plant tissue culture. Tissue culturing has been important in the development of nearly all transgenic plants, or plants that incorporate genes from some other source. This process allows a plant breeder to grow an entire plant from only a few plant cells.

New technologies have been developed in animal biotechnology as well. After years of using artificial insemination, the livestock industry gained another application of biotechnology with the development of embryo transfer techniques in the early 1980s. Methods of cloning animals have also been developed. In 1981, a Chinese scientist first cloned a fish. In Scotland in 1997, a ewe named Dolly was the first animal to be cloned from the cells of an adult mammal. Also in 1997, a calf named Gene was cloned from cells taken from a 30-day-old fetus.

The ability to alter DNA through genetic engineering has made many new products possible. The first genetically modified food product, an enzyme used in making cheese, was approved for use in the United States in 1990. Today, this enzyme is used to process most of the hard cheese produced in the United States. The first genetically modified crop plant was approved in the United States in 1994. This plant was the FlavrSavr™ tomato, which was engineered to taste better and have a longer shelf life. Insect-resistant and herbicide-tolerant crops were approved for use in the United States in 1995 and 1996. Animal vaccines produced from genetically modified bacteria were developed in the mid-1990s.

The future applications of biotechnology are not easy to predict. Several biotechnology products are currently being researched. Some of these products include environmentally tolerant crops and plants genetically modified to be used for biofuels. The future applications of biotechnology will address specific problems or obstacles preventing higher yields and higher quality agricultural products.

Consumer Perspectives toward Agricultural Biotechnology

Agricultural biotechnology is typically viewed by consumers as both positive and negative. Consumers in developed countries such as the United States like the idea of lower food costs, increased nutrient content, and having fresh fruits and vegetables available year-round. In developing countries, the interest is mainly in increased and cheaper food supplies.

However, some consumers in both developed and developing countries have concerns about the use of biotechnology. Some people fear that foods produced in this manner may not be safe to eat, even though U.S. regulatory agencies have stated that genetically modified foods are as safe as unmodified foods. Consumers also fear that agricultural biotechnology could harm or endanger the environment if genetically altered organisms are released.

The perspective of the consumer is an important factor in determining the market potential for products developed through biotechnology. Whether their fears are valid or not, consumers make the final decision about whether to purchase biotechnology products. Therefore, their concerns must be addressed.

Producer Perspectives toward Agricultural Biotechnology

Producers of agricultural products may also have both positive and negative feelings toward biotechnology. Producers see the potential for increased profits due to higher yields or lower input costs. Producers also see a benefit in reducing the amount of chemicals applied to their crops through the use of pest-resistant plants, since water supplies on their land would be better protected from contamination. Profitable new “customized”

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crops will benefit producers as well. Examples of customized crops are corn developed specifically for the production of ethanol or carrots developed for carrot stick snacks. Producers will receive premium prices for these types of crops.

Agricultural biotechnology does raise concerns among producers. Producers fear that small farms may not have the opportunity to use biotechnology and that large corporate farms may become more competitive and force them out of business. They also fear that a genetically modified crop could create a “super weed.” The genetically modified plant could cross pollinate with a wild plant species to produce a plant that is nearly impossible to control. The debate continues as to whether there is any justification for these fears.

Nonagricultural Impacts of Biotechnology

Agriculture is only one of the areas affected by biotechnology. The human health industry, and particularly the producers of pharmaceuticals, have been greatly affected by biotechnology. Insulin for diabetics, for example, is now produced by genetically modified bacteria. It was the first product made by genetic engineering to be approved for sale in the United States. Many human vaccines have been developed using the same method, including a vaccine for rabies. Some human antibiotics and human growth hormones can be produced using modified bacteria. Biotechnology has also affected the health industry through the development of tests that detect genetic disorders. Huntington’s disease, Down’s syndrome, Tay-Sachs disease, and cystic fibrosis can all be detected much earlier because of tests developed through biotechnology.

Another industry that is benefiting from biotechnology is the mining industry. Bacteria are being genetically modified for biomining. They will break down poor quality heavy metal ore. The metal can then be extracted much more easily. The bacteria will allow ore to be used that was once too costly to process.

Law enforcement and the criminal justice system have begun to use DNA for forensic purposes. A process called DNA fingerprinting can help to identify individuals who have committed a crime. It can also be used to match a child with its biological parents in cases where they have been separated due to war, kidnapping, or other circumstances.

The waste treatment industry and companies that clean up pollution are testing the use of genetically modified bacteria to treat sewage, clean up oil spills, and improve soil contaminated with organic compounds such as DDT. These bacteria literally feed on the undesired compound. Solid waste sites like landfills are examining the use of modified bacteria that will feed on the waste and give off methane gas, which can be burned as a fuel.

Summary

Biotechnology is the application of science to living things. Biotechnology has affected plant and animal production and the food processing industry, but it is also very important in many other areas, such as human health, mining, law enforcement, and waste disposal. Consumers and producers of recent products of agricultural biotechnology view them from different perspectives. These perspectives will influence the direction and pace of research in biotechnology in the future.

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