Biotechnology

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Biotechnology is broadly defined as the use of living systems, organisms, or biologically derived materials to develop or make products. It is fundamentally, applied biology and increasingly, the interface between biology and engineering. While the word biotechnology is credited to Károly Ereky, who coined the term in 1919 in a book entitled *Biotechnologie der Fleisch-, Fett- und Milcherzeugung im landwirtschaftlichen Grossbetriebe* (*Biotechnology of Meat, Fat and Milk Production in an Agricultural Large-Scale Farm*),[1] applications of living systems to derive products predate this definition by millennia. The earliest applications of living organisms to create novel products are in the area of food fermentation. Beer making in China is believed to have occurred at ~7000 BCE, followed by yogurt and cheese at ~6000 BCE and the use of yeast to make leavened bread in Egypt at ~4000 BCE. However, what we will come to know as agricultural biotechnology can be traced to the domestication of food animals and cultivation of plants at c. 9000 and 8000 BCE, respectively. Even the areas of medical biotechnology and industrial biotechnology are far older than commonly realized; in China, moldy soybean curds were used as an antibiotic in ~500 BCE and chrysanthemums were used as an insecticide in ~CE 100.

The underpinnings of what we would consider modern biotechnology can be traced to the late Renaissance period, with the development of the microscope by Zacharias Janssen in 1590 and the discovery of the cell by Robert Hooke in 1663, followed by the discovery of bacteria by Antonij van Leeuwenhoek 12 years later. The first vaccine (against smallpox) was developed in 1796 by Edward Jenner, and nearly 70 years later, in 1861, Louis Pasteur developed pasteurization to protect food against spoilage. Since the late 19th century, advances and discoveries in biotechnology have grown at an exponential rate, including development of the first hybrid corn in a laboratory in 1870, the discovery of penicillin by Alexander Fleming in 1928, and the description of the double helical structure of DNA by James Watson and Francis Crick in 1953 (for which they received the Nobel Prize, along with Hugh Wilkins, in 1962). A number of other key advances in the 1960s and 1970s led to the development of recombinant DNA technology by Stanley Cohen and Herbert Boyer in 1973, in an experiment in which they inserted a gene from an African clawed toad into bacterial DNA. Following up on this technological breakthrough, Herbert Boyer and venture capitalist Robert Swanson founded Genentech, the first biopharmaceutical company in 1976. Genentech produced the first human protein (somatostatin) in *Escherichia coli* in 1977, and in 1982, recombinant human insulin (developed by Genentech and licensed to Eli Lilly) became the first recombinant DNA drug marketed. Recent advances in nucleic acid sequencing have thrust us into the genomic era, providing new understanding of human disease and new strategies for engineering agricultural systems to provide adequate food for the 21st century population.

Today, biotechnology pervades all aspects of our daily life; it affects the foods we eat, the safety of the water we drink, the clothes we wear and how we wash them, the medications we take, and the gasoline we put into our cars. This section on biotechnology provides a comprehensive overview of the what, why, and how of biotechnology and bioprocessing. Initial sections focus on the wide range of biological systems that are used to carry out biological transformations including enzymes, bacteria, yeast and other fungi, mammalian and insect cells, plants and plant cell cultures, and transgenic animals. The next section focuses on the applications or end products of these biological transformations. These products include: industrial products (sometimes referred to as white biotechnology), including bulk and specialty chemicals, biofuels and biopolymers; medicinal products (sometimes called red biotechnology), including small biomolecules (eg, antibiotics), therapeutic proteins, vaccines, and cell-based products; and finally, food and agricultural-based products (sometimes described as green biotechnology). The final section discusses the bioprocesses, the engineering systems that permit the biological systems to transform their substrates into the desired bioproducts. In this section, a variety of reactors are discussed, including enzyme reactors and microbial and mammalian cell bioreactors. Separations processes, which are critical for obtaining the desired product purities are covered next, followed by process engineering and control, which are essential for obtaining the desired products at adequate concentrations in a cost effective manner. Next, the biological tools for performing the manipulations of the cells such as vector design, metabolic engineering, synthetic and systems biology are reviewed. The final sections discuss the analytical tools used to verify that the correct DNA sequences have been inserted into the cells, that the cells are behaving as expected, and that the correct products, with appropriate biological activity, have been produced.

Today, we live longer, healthier lives than at any other time in history. While biotechnology cannot solve all of the problems and challenges that confront us today, it has played an important role in human development and will continue to do so. Better living through biotechnology!

Reference

1. Ereky, K., 1919. Biotechnologie der Fleisch-, Fett-, und Milcherzeugung im landwirtschaftlichen Grossbetriebe: für naturwissenschaftlich gebildete Landwirte verfasst. Berlin: P. Parey, p. 84.