The SAGE Encyclopedia of Stem Cell Research

New Biotech: Overview

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There are many definitions of “biotechnology” and they cover a wide variety of fields and practices. Simply explained, biotechnology is technology based on biology. Some of the most commonly used definitions are provided by the National Institute of Food and Technology of the U.S. Department of Agriculture and by the United Nations Convention on Biological Diversity. The National Institute of Food and Technology provides a general definition of biotechnology as the field that develops useful products and services using biology, biology derivates, and biological processes.

According to the United Nations Convention on Biological Diversity, biotechnology refers to technological applications that use biological systems or derivates in order to create products for human use, or in order to modify existing ones. In general, then, biotechnology can be described as the use of biological organisms, systems, products, and processes by diverse organizations and industries in order to study biological structures and functions and for the modification of products such as crops, livestock, and chemicals to enhance them. The field of biotechnology has much in common with the fields of biomedicine and bioengineering, as well as with other related fields, such as chemical engineering and biochemistry, bioprocessing, biorobotics, cell biology, genetics, molecular biology, microbiology, animal cell culture, and many others. All these fields are not necessarily exclusive of each other.

Experts believe that biotechnology, by way of manipulation of biological microorganisms to make and preserve useful food products, has existed for over 6,000 years. In its role of modifying live organisms to serve human purposes, it goes back to the domestication of animals, the development of early agriculture, and using plants for medicine. These modifications include improvements to these practices, such as plant hybridization, selective animal breeding for food and hunting, and the manufacture of products such as bread, wine, cheese, and other dairy products. All of these processes have employed measures of artificial selection and manipulation, which remain at the root of modern biotechnology. In many ways, then, this technology as known today began with these husbanding and agricultural processes.

In general, biotechnology has applications in four major sectors: crop production and agriculture, health care and medicine, industrial use of crops and other products to create items such as biofuel and biodegradable products, and in the environmental sector. Although a common application of biotechnology is the manipulation of live organisms for the creation of food products, it is also commonly used for myriad daily processes, such as treating waste, cleaning sites contaminated by industrial wastes, and even producing biological weapons. All uses of biotechnology are color-coded for identification.

The application of biotechnology in the medical and health fields is known as red biotechnology, and includes, for example, the development of medicines and treatment for diseases through genetic manipulation. Green biotechnology is also known as agricultural biotechnology, referring to its uses in growing crops and raising animals for food production. White biotechnology, also known as industrial biotechnology, is biotechnology applied to a wide array of industrial processes. One of the advantages of industrial biotechnology over traditional technological systems is that, in general, it utilizes less resource inputs in the production of industrial wares.

Finally, blue biotechnology refers to the application of biotechnology to marine and aquatic organisms and processes, a relatively new and not yet advanced branch of biotechnology. The color codes by which biotech fields are known refer to their applications in the market, except blue biotechnology, which refers to its key element—water. However, it is important to

note that, strictly defined, the applications of blue technology overlap with the other types of biotechnology, so that even processes such as aquaculture are really another type of green biotechnology.

Finally, biotechnology is a discipline that depends upon and overlaps with many other fields. Millions of dollars are invested each year in a wide array of biotechnology activities. All economic activity of any branch of biotechnology is known as bioeconomy. New biotechnology discoveries are constantly realized in research and development laboratories funded by bioeconomy. These influence many disciplinary areas, as biotechnology itself is a multidisciplinary field. That means that it encompasses and runs across many different fields in order to get results. In the laboratory setting, for example, besides techniques related to chemistry, biology, and engineering, biotechnology uses bioinformatics to study, extract, and create products from live organisms through biochemical engineering processes.

Bioinformatics, also known as computational biology, examines biological organisms and systems using computing technology. It facilitates the rapid compilation, categorization, and analysis of biological data. Moreover, bioinformatics plays important roles in various other biologic-related fields, such as in pharmaceuticals, genomics, and bioengineering. Bioengineering also overlaps diverse fields, as it refers to the discipline that applies principles of engineering and the natural sciences to living molecules, cells, and tissues. This is usually done to manipulate biology in order to improve functions in living organisms. Bioengineering itself is an important field that interrelates with myriad subfields, such as biomedical, chemical, biopharmaceutical, genetic, and other types of biology-related engineering.

Agricultural Biotechnology

Also known as green biotechnology, agricultural biotechnology is biotechnology applied to agriculture, for example, designing transgenic plants to grow in specific environments, with or without the support of chemicals. One of the principal goals of agricultural biotechnology is to produce crops using methods more beneficial to the environment than traditional industrial agriculture practices. A genetically modified crop such as corn, for example, can be engineered to incorporate and express a pesticide, thus eliminating the need for the external application of chemicals.

However, whether green biotechnology can accomplish the goal of producing genetically modified plants more beneficial to the environment is an issue of much debate. Genetically modified (GM) crops are agricultural plants whose DNA has been modified via genetic engineering in order to express in the crop a characteristic that does not naturally occur in its species. Other examples of biotechnology processes in food crops include improving the nutrients in crops, creating ingrown resistance to specific agricultural diseases and pests, or developing resistance to certain chemicals and to unfavorable environmental conditions.

Despite persistent controversy and debate, millions of farmers worldwide have adopted green biotechnology to increase agricultural yields, prevent damage from pests, and reduce the environmental impact of farming. Today, it is estimated that over 10 percent of the world's cultivated lands are planted with genetically modified crops. Moreover, to date, about a dozen species of transgenic crops are produced commercially in the United States, Australia, and Spain, as well as countries across Africa, Asia, and Latin America.

Genetically modified foods are foods produced from organisms that, through methods of genetic engineering, have had changes or modifications introduced into their DNA. These

techniques have opened the door for the introduction of more new crop traits and better control over the genetic structure of plants than ever possible by traditional methods. Commercial uses become increasingly commonplace. The marketing of genetically modified foods began in 1994, with the creation of a delayed-ripening tomato. Today, there is great demand for genetically modified food technology, especially to produce crops for corn, soybean, and canola oil, among other products. These crops have been modified to offer better nutrients and for resistance to herbicides, pests, and disease. Today, there are also innovative experiments developing for genetically modified livestock, although none have been commercialized to date.

Although many scientists agree that foods produced from genetically modified crops are as safe for human health as food marketed from traditional sources, and that genetically modified farming technologies can provide some ecological benefits, opponents have objected to genetically modified crops for several reasons. These include not only environmental concerns but also concerns about the safety of food produced from genetically modified crops. Questions have also been raised as to whether such crops can actually supply foods sufficient to meet global needs, and whether these crops and their genetic matter can be privatized under intellectual property laws.

Experts argue that biotechnology can help increase food distribution worldwide—and decrease global hunger—by reducing the amount of chemicals required for farming and producing greater harvest yields. Biotechnology allows farmers to produce more food with less work and to develop crops with enhanced nutrition that can help reduce nutrient deficiencies. Moreover, biotechnology facilitates the production of allergen- and toxin-free foods and lower food oils to help improve cardiovascular health. Many expect that for the foreseeable future, food production scientists will continue to create new types of plants and microorganisms.

Medical Biotechnology

Biotechnology is helping to deal with persistent health problems by developing useful processes through genetics to reduce the rates of infectious disease, tailor treatments to individuals to ensure minimal risks and side effects, create more accurate equipment for disease detection and diagnosis, and combat debilitating and serious health threats in poor communities and developing nations. The field of medicine is an important development and performance arena for biotechnology. In the health and medical fields, biotechnology today is producing cutting-edge innovations in genetic testing, drug discovery, and development or pharmaco-genomics. For example, modern biotechnology can be used to manufacture existing medicines relatively easily and inexpensively.

Among the first genetically engineered products, manufactured in the 1970s, was a medication designed to treat human disease: synthetic humanized insulin. Prior to that, insulin, a vital medication used in the treatment of diabetes, was extracted from the pancreas of cattle and swine, a costlier and less efficient procedure. The manufacture of synthetic human insulin by genetically engineered means has allowed the production of large amounts of the drug at a lower cost. Biotechnology has also opened the door to helpful new technologies, such as gene therapy, and significantly improved the understanding of biological processes. In general, biotechnology has increased the ability to develop new medications as well as to diagnose, treat, and cure previously incurable and chronic diseases.

Genetic testing today has many uses. It has made great strides toward identifying risk for

inheritable diseases and, through the study of chromosomes, can also be used to determine an individual's progenitors and ancestry back through many generations. The technology of genetic testing also includes biochemical tests for the existence of genetic disease, that is, identifying mutant genes implicated in a higher vulnerability of developing genetic disorders. Genetic testing can also identify mutations in chromosomes and proteins. The majority of genetic testing is used to identify mutations associated with inherited diseases and disorders. A genetic test can identify or rule out the possibility of a genetic disorder, and it can also help identify an individual's risk of developing or passing on to his progeny a genetic condition. More recently, medical research has been moving toward creating a genetic roadmap that offers the possibility of finding the origin of many genetic disorders and conditions. Recent studies have also uncovered ways in which heredity and environment can affect genetic expression in individuals, even of psychological conditions. However, because multiple genes may be involved in a specific disease, identifying the genetic causes of particular diseases is a very complex issue. Moreover, genetic expressions often do not appear directly but do so by activating other genes.

Other recent discoveries in medical biotechnology have occurred in the area of cardiovascular health and include the development of a biological pacemaker and absorbable heart stents. A biological pacemaker, unlike electronic versions of the instrument, will not wear out and can be introduced via stem cells into the heart. Stents widen arteries that have become obstructed due to heart disease. Unlike conventional stents, the new absorbable version dissolves into the organism once it has performed its function, leaving a healthy artery. Medical biotechnology has also achieved advances in nerve regeneration for spinal cord injury, muscle stimulation to help muscles avoid atrophy when immobilized for a period of time, the creation of organs for transplant, and many other life-enhancing possibilities.

Industrial Biotechnology

Industrial biotechnology, also known as white biotechnology, has many manufacturing and commercial uses today. For example, it is used in fermentation. By processing non-alimentary crops, it can produce goods such as pharmaceuticals and biofuels. Its technology includes the use of microorganisms and enzymes to manufacture industrial products such as food, chemicals, paper, detergents, and biofuels, among many others. Industrial biotechnology may contribute to reducing both greenhouse gas emissions and dependence upon more harmful petrochemical fuels.

In regard to fuel, biotechnology uses processes such as fermentation and other biological catalysts such as microorganisms and enzymes to create fuel. Biofuels have existed for hundreds of years in the form of wood, coal, and animal waste for the generation of heat and energy. Today, corn, sugarcane, and other plants can be processed into ethanol, which can be mixed with gasoline or used alone in some types of engines. The latter are cleaner types of energy, experts say, than the fossil fuels commonly used. Biotechnology supporters argue that one of its main advantages is its capability to significantly lower environmental impact for industry and households. The use of biofuels can reduce greenhouse gas emissions by over 50 percent, vastly streamline chemical manufacturing processes, improve other manufacturing processes and efficiency, reduce use of and reliance on fossil fuel, exploit the processes of some waste products, reduce water usage, and many other processes advantageous to the environment.

In 2014, several dozen biorefineries are in the process of development across North America in order to research and refine biofuel technology and renewable biomass chemicals. It is

expected that this will significantly help to reduce the effect of greenhouse gas emissions. Critics, however, warn that the production of biofuels requires too much farm land to be sustainable and its mass production could cut into food production. And producing biofuels uses much more energy than the fuel can generate.

Biotechnology Policy and Regulation

Biotechnology products have new biological properties and are relatively untested. Therefore, as with all new technology, they may pose risks and call for regulatory measures. The government agencies in the United States in charge of regulating, controlling, and supervising these products and their development are the Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA), and the Food and Drug Administration (FDA). These three organizations share the responsibility for regulating agricultural biotechnology in the United States. The EPA is in charge of regulating pesticides created through biotechnology as part of its jurisdiction over all pesticides sold and used in the country and as part of its mandate to examine research analyzing risks to human health.

The USDA is in charge of protecting national agriculture against pests and diseases. As such, it regulates the testing of genetically engineered plants as well as the approval of biotechnology products such as animal biological substances, including animal vaccines. USDA responsibilities include the regulation of any crop practices that do not fall under the jurisdiction of the EPA.

The FDA examines and regulates food safety practices and the nutritional factors of new plant varieties. The FDA's biotechnology policy is grounded on existing food law and regulations. Genetically engineered foods must abide by the same safety standards required of all other foods distributed in the United States. The FDA is also in charge of food labeling standards.

In general, most experts agree that biotechnology poses risks that can be managed by following good business practices and sound science. These steps include ensuring a transparent decision making process, consistency and fairness, collaborating with regulatory agencies, maintaining public trust, and peer-review practices.

Although biotechnology provides the means by which valuable and useful products can be developed, produced, and marketed, research organizations and industrial concerns must often acquire national and even international approval for the results of animal and human experiments. This is especially true for the pharmaceutical and genetic engineering branch of biotechnology, to avoid provoking any undetected public safety risks. For example, some biotechnology processes require using plasmic bacteria, which many fear might be transmitted to humans, with effects yet unknown. Differences exist internationally in regulations for genetically modified organisms, especially between the European Union and the United States. The cultivation of genetically modified organisms (GMOs) is a topic of debate among supporters and opponents of GMO technology. One of the main points of contention is the coexistence between conventional crops and genetically modified crops and the possibility of crop contamination from GM plants to conventional plants.

Other controversies have arisen regarding the patenting of human and nonhuman genes. Patents on genes or gene components have been granted in many countries around the world, and the topic has been the source of debate for decades. Many are deeply opposed to the possibility of patenting elements of the human or other genomes. Critics posit that claiming a patent over the shared genetic heritage of humanity is inherently unethical. The

debate in the legal arena revolves around determining whether the genes in question are a product of nature. Under U.S. law, products of nature cannot be patented. There are many other ongoing debates in reference to the ethics, advantages, and disadvantages of biotechnology, such as issues related to cloning, potential dangers of some biotechnology processes, accountability and responsibility of practitioners, unwanted hybridization of genetically engineered crops, export regulations and restrictions, and more.

Supporters, however, maintain that biotechnology offers numerous advantages for society and that the field often suffers from public misperceptions due to the complexity of its nature. Recent advances in biotechnology continue to trigger the development of cutting-edge technology and breakthrough products in a wide variety of fields worldwide, with promising possibilities for feeding the hungry, combating disease, reducing the environmental footprint, and designing safer and more efficient industrial manufacturing processes.

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See Also: Animal Cloning; Genome Sequencing; Heart Disease; Tissue Engineering (Scaffold).

Further Readings

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