

The future of genetic engineering in biotechnology

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Introduction

To the everyday person, it is not common knowledge that Biotechnology has been in existence for many centuries. Today, scientists are introducing many innovative bio-technological advancements, but many people are not aware that the first uses of biotechnology date back to 7,000 BCE.¹ A basic definition of biotechnology is “the use of living organism/s or their product/s to modify or improve human health and human environment”.² On a broader scale, biotechnology is essentially the engineering of biological organisms for the purpose of human use.³ Whether it be for medicine, agriculture, industrial, or marine purposes, biotechnology has become a leading source of biologic science with unlimited potential touching many aspects of everyday life.³ There are three distinct phases that pertain to the history of biotechnology: Ancient Biotechnology (Pre - 1800), Classical Biotechnology (1800-1945), and Modern Biotechnology (1945-present).¹

History of biotechnology

Ancient biotechnology

Dating back to around 7,000 BCE, Ancient Biotechnology emerged to be the most primitive form of biotechnology.³ During the ancient phase, most of the “inventions” were said to be developed by observing nature.² These observations resulted in discovering products to help human life, but people did not understand how or why it worked.² Human beings began domesticating animals and cultivating plants to use as a reliable source of food.³ The earliest examples of cultivated plants are food items such as rice, barley, and wheat.³ Around 4,000 BCE, ancient Egyptians discovered that they could use yeast to make bread and brew beer.⁴ Soon after, fermentation techniques were developed for cheese making and wine production.¹ Ancient Egyptians used honey to treat respiratory infections and as an ointment to heal wounds.⁵ By using moldy soybean curds, China developed the first antibiotic used to treat boils in 500 BCE.¹ It was in the 17th century that scientists discovered cells, microorganisms, protozoa, and bacteria.¹ These discoveries lead to the development of the first vaccine.¹ In the eighteenth century, Edward Jenner inoculated the first child with a smallpox vaccine.¹ Although this version of a vaccine was not “clinically tested” and still in a “trial phase”, Jenner’s discovery ultimately led to vaccines being widely accepted by the public and has saved many lives throughout history. This event could very well have been the turning point for biotechnology and how it has become what it is today.

Classical biotechnology

The second phase of biotechnology is known as Classical Biotechnology and its time ranges from 1800 to 1945.¹ The discoveries made by Edward Jenner in the Ancient Biotechnology period paved the way for scientific advancements and exploration.¹ In 1855, *Escherichia coli* bacterium (*E. Coli*) was discovered and is now used daily in laboratories around the world for research, development and production purposes.¹ A lot of the advancements in biotechnology stem from genetic information as well.² It was in

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the Classical period that Gregor John Mendel discovered that plants contain genetic material.² From his publications in 1866, scientists were able to determine that genetic material contains observable traits, later termed the name genes.² Many groundbreaking discoveries were uncovered in the classical biotechnology phase. The first corn hybrid was produced in 1870 and was then commercialized in 1933, genes were linked with hereditary disorders in 1909, phages were discovered in 1915, the first use of the term “biotechnology” was in 1919, in 1928 Alexander Fleming discovered the penicillin and the antibiotic started being mass-produced in microbes in 1942.¹ Many of the building blocks of biotechnology were being developed at an exponential rate which opened many doors for the crucial discoveries in modern biotechnology.

Modern biotechnology

During the Modern Biotechnology period, 1945 to present day, genetic engineering culminated.¹ The modern era of biotechnology initiated the revolutionary discoveries that have brought this field to its current status. The two events that are thought to have united genetics with biotechnology are the discovery of the double helix structure of DNA by Watson and Crick in 1953 and also the technique of recombinant DNA discovered by Cohen and Boyer in 1973.¹ Today, much of biotechnology research revolves around genetic engineering and what we can accomplish with the concepts brought forth by gene and protein manipulation.⁵ Some other scientific breakthroughs in the modern era include the harvesting of animal cell cultures in 1945, the concept of central dogma came about in 1957, in 1966 the genetic code was cracked, in 1972 Paul Berg synthesized the first recombinant DNA molecule, the US Supreme Court passed that genetically modified organisms could be patented in 1980, the first draft of the human genome was created in 1998, and the gene-editing technology CRISPR has been developed that has led to many genetic breakthroughs.³ These are just a few of the innovative discoveries that have been made during the Modern Biotechnology era.

With all advanced technology, there is also potential for misuse.³ There are many fields that can be seen as unethical or harmful such

as human cloning or bioterrorism.³ Governments around the world are continuously researching ways to prevent bioterrorist attacks and develop weapons of their own.³ The true defense against biological warfare is understanding the fundamentals and being prepared for the worst possibilities. There is enormous potential for greatness in the future of all branches of biotechnology. The advanced discoveries revolving around genetic manipulation has positioned this field as a leading industry for the future of science.¹ Overall, the ultimate goal of biotechnology is to enhance the lives of humanity in a beneficial way.

Genetic engineering in biotechnology

Biotechnology has become one of the leading industries in the scientific field.¹ There are many segments of biotechnology ranging from agriculture to aquatics. One component of biotechnology that is not considered as a segment is genetic engineering.⁶ Although this topic may be considered an application of biotechnology by some, it has been said that biotechnology would not be where it is today without the technological advances of genetic engineering.⁶ Dating back to the Ancient Biotechnology phase, artificial selection was one of the earliest forms of genetic engineering applications introduced into societal practices.⁶ Also known as selective breeding, artificial selection was used to choose mating pairs between plants or animals.⁶ Altering the DNA and genetic makeup of plants and animals has become a standard practice in the agricultural, medical, and industrial segments of biotechnology today.⁶ Genetic engineering, gene amplification, gene therapy, and gene editing are all fundamental operations used on an everyday basis to benefit the lives of society.⁶

Market size and trends

According to a new market research report, published by Markets and markets in November of 2021, the global market for genome engineering and genome editing is projected to reach \$11.2 billion dollars by 2025.⁷ In 2020, the global market reached \$5.1 billion.⁷ During this forecast period, the projected current adjusted gross rate should show a 17% increase.⁷ However, the concentration of market leaders in North America and Europe may prove to lessen the chance of global market expansion in other regions of the world.⁸ The market growth rate is largely attributed to the increase in government funding, rise in the number of genomics projects, technological advancement, the need for action against infectious diseases and cancers, and the growing application range of genomics in general.⁷

It has become evident that there is a lack of research and development within the genome engineering sector and may prove to inhibit the growth of the global market worldwide.⁸ By technology, the CRISPR segment is anticipated to be the largest shareholder in the projected timeline.⁷ This gene editing technology proves to be easily operated for research and cell line engineering applications which is ultimately believed to be a considerable contributor to the global market growth as well.⁸ By application, cell line engineering is anticipated to have the largest projected growth rate in the projected timeline.⁸ Many companies in the cell line engineering industry are focusing on stem cell research because governments and private sectors are providing increased funding for new stem cell research projects.⁷

Leading shareholders

In 2019 and 2020, North American genome engineering companies accounted for the largest share of the global market.⁷ As a result, the North American genome engineering market is anticipated to have the largest growth rate followed by the European market.⁸ The leading genome engineering companies located in the United States are:

Transposagen Biopharmaceuticals, Thermo Fisher Scientific, Editas Medicine Inc., OriGene Technologies, Intellia Therapeutics Inc., GenScript, Sangamo BioSciences, Integrated DNA Technologies, Bluebird Bio Inc., New England Biolabs, and Editas Medicine.⁸ Some European companies that are also in contention with the North American region are: Merck (Germany), Lonza Group (Switzerland), Horizon Discovery Group (UK), Collectis S.A. (France), and CRISPR Therapeutics (Switzerland).⁸ These sixteen companies are considered to be the leading shareholders of the genome engineering industry worldwide.⁸ The Asia Pacific Region is quickly proving to be one of the fastest growing regional markets due to the increase in projects and investments being spent on gene synthesis, but the Asia Pacific region is still considered the third projected market for growth.⁷

The future of genetic engineering

As stated previously, much of biotechnology research revolves around genetic engineering.⁵ This trend does not seem to be slowing down in any capacity, but rather the opposite. Genetic engineering has received more attention in the past decade than any other sector of the biotechnology field. More projects are being approved due to the large investment interest.⁷ From the trends that have become apparent recently, the future of genetic engineering lies in gene therapy and next generation sequencing.

Gene therapy

Gene therapy is a unique technique that attacks disease at a molecular level, probing to replace damaged molecules.⁹ Administration of gene therapy can be done either through *ex vivo* or *in vivo*.⁹ *Ex vivo* works by isolating cells with a genetic defect, modifying them outside of the body, and then reinserting the modified cells back into the body to naturally fight off disease.⁹ *In vivo* works by transferring a functioning gene into a vector and injecting it directly into the bloodstream.⁹ Another relevant discovery shows that stem cells have been a large part of the gene therapy advancements being introduced today.⁹ Stem cells have proven to be extremely valuable to gene therapy because they are not specific to any organ of the body.⁹ Because of this, stem cells have been able to reprogram cells in the body in order for damaged cells to be replaced by healthy cells.⁹ Gene therapy will change the way that we approach disease and the preparation of personalized treatments.

Genetic sequencing

In conjunction with gene therapy, next generation sequencing is a valuable asset for the future of genetic engineering. There was a large gap between the demand for information and the capacity of traditional sequencing technologies.¹⁰ Next generation sequencing has revolutionized the biotechnology field, allowing researchers to run sequencing schemes on a larger level than ever before.¹⁰ With that being said, next generation sequencing technology has the capacity to rapidly sequence whole genomes, identify target regions, and analyze epigenetic factors present in the genetic makeup of a sample. This type of technology makes it possible for researchers to sequence an entire genome within an accelerated time frame. With next generation sequencing, companies will be able to conduct more research and release innovative breakthroughs at a rapid pace.

Conclusions

Gene therapy and next generation sequencing, together, will lead the biotechnology field to a fulfilling future. Oncology would greatly benefit from targeted treatments that are developed through the use of both practices. Because cancer does not have a direct

cure, the progression of gene therapy research would ultimately lead to the successful targeting of certain cancer cells. Using next generation sequencing may be able to target the genes that would stop the replication process of diseased cells before it progresses to an uncontrollable rate. A discovery like this would be a medical breakthrough bettering the lives of many patients. Gene therapy and next generation sequencing segments of biotechnology will eventually lead to cures for diseases we thought to be incurable. There is an exciting future for genetic engineering, we just need to focus our efforts in unveiling the potential that it has to offer.

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Conflicts of interest

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