BIOTECHNOLOGY: DEFINITIONS, TYPES AND MAIN APPLICATIONS

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ABSTRACT

Biotechnology is a multidisciplinary field that utilizes living organisms or their components to develop products and processes that benefit human society. It draws on a range of scientific disciplines, including molecular biology, genetics, biochemistry, and engineering, and has made significant strides in recent years. Biotechnology has had a significant impact on various aspects of our lives, such as healthcare, agriculture, industry, and the environment. Its contribution to the development of new drugs, vaccines, and diagnostic tests has been invaluable, while its role in increasing crop yields and improving nutritional content has enhanced food security. Moreover, biotechnology has enabled the production of sustainable and environmentally friendly products and materials. Biotechnology is a technology of hope, with the potential to improve human health, raise living standards, and protect our planet.

The aim of this paper is to provide a comprehensive overview of biotechnology, including its definitions, types, and main applications. The paper will explore the fundamental principles of biotechnology and the various subfields it encompasses. It will also provide an in-depth analysis of the most significant applications of biotechnology in healthcare, agriculture, industry, and the environment. Ultimately, the paper seeks to increase awareness and understanding of biotechnology and its impact on society, while also highlighting potential areas for future research and development.

Keywords: Biotechnology, multidisciplinary, applications, biotechnology areas, biotech advancements.

1. INTRODUCTION

Biotechnology is multidisciplinary field which has major impact on our lives. The technology is known since years which involve working with cells or cell-derived molecules for various applications. It has wide range of uses and is termed “technology of hope” which impact human health, well being of other life forms and our environment **(Gupta et al.2016)**.

The basic principle of biotechnology is to use living organisms or their components, such as cells, enzymes, and proteins, to create new products or processes. The techniques and applications of biotechnology are diverse and have a broad range of applications. Biotechnology uses science and engineering to process materials with biological agents **(Chekol C. 2018)** .Biological agents such as enzymes, plant cells and microorganisms are used to produce pharmaceuticals, foods and biochemical used for warfare Its application is held in nanotechnology, cloning, gene therapy, recombinant DNA technology, embryonic stem cell research, biofuels, biobanks, and in biotechnological industries. Chekol C (2018) emphasizes that Biotechnology and bioindustries are becoming an integral part of the knowledge-based economy, because they are closely associated with progress in the life sciences and in applied sciences and technologies linked to them.

In the agricultural sector, biotechnology has helped to increase crop yields and improve the nutritional content of crops. Biotechnology has also enabled the development of genetically modified crops that are resistant to pests and can grow in harsh environmental conditions, such as drought. In addition, Reverse breeding methods are also used to accelerate breeding and create new cultivars to meet changing climate demands .The applications of plant biotechnology are responding to the increasing demands for food security, socio-economic growth, conservation, diversification, and sustainable use of plant genetic resources as fundamental components of the future agricultural sector **(Bentahar S & Ykhlef N.2023).** In industry, biotechnology has led to the development of new products and materials that are sustainable and environmentally friendly. Biotechnology has enabled the production of biofuels, bioplastics, and enzymes for use in laundry detergents, among other things. Moreover, in the field of the environment, biotechnology has the potential to address some of the most pressing global challenges, such as climate change and pollution. Biotechnology can be used to create new biodegradable materials, clean up contaminated sites, and produce sustainable energy sources. Finally, biotechnology is a rapidly evolving and dynamic field that has the potential to address some of the most pressing challenges facing society. It has transformed various industries and has led to the development of new products and processes that have improved human health, increased food security, and created a more sustainable world.

The purpose of this article is to undertake an in-depth exploration of biotechnology and its various subfields, with a focus on critically analyzing its most significant applications in healthcare, agriculture, industry, and the environment. By providing a comprehensive examination of biotechnology, this study aims to enhance scholarly knowledge and understanding of its impact on society, while also identifying promising areas for future research and development.

2. DEFINITIONS OF BIOTECHNOLOGY

The term "biotechnology" was coined by a Hungarian engineer Karl Ereky, in 1919, to refer to the science and methods that permit products to be produced from raw materials with the aid of living organisms. Biotechnology is a diverse field which involves either working with living cells or using molecules derived from them for applications oriented toward human welfare using varied types of tools and technologies. It is an amalgamation of biological science with engineering whereby living organisms or cells or parts are used for production of products and services **(Gupta V et *al*.2016).**

There exist a vast variety of definitions of biotechnology. The definition of the OECD (Organization for Economic Co-operation and Development) should be given here. It says that „Biotechnology is interdisciplinary branch of science and technology dealing with transformation of living and inanimate matter by the use of living organisms, their parts or products derived from them, as well as creation of models of biological processes in order to produce knowledge, goods and services.

Three generations of biotechnology have been proposed, beginning with the use of whole organisms (initially, unknowingly) in fermentation – for example, in brewing. The second generation exploited greater microbiological understanding and led to development of culture and extractive techniques in the first half of the twentieth century (e.g., for the production of antibiotics from fungi). The third generation, dating from the 1970s, is related to the isolation and application of restriction enzymes and monoclonal antibodies (e.g., recombinant production of insulin in bacteria, monoclonal drugs from mammalian cell hybridomas) **(M.M. Hopkins et *al*.2007).**

Modern biotechnology is one tool that can help meet the challenge this growth poses and also contributed to (a) ecofriendly environment (b) safety and health, (c) reduced water demand in manufacturing processes, (e) reduced industrial waste and (f) aided in pollution remediation. **(Vigneswaran et *al.* 2014).**
In general, biotechnology uses either living material or biological products to create new products for their use in various pharmaceutical, medical, agricultural, and environmental applications, with the ultimate goal to benefit humanity, for example, production of recombinant proteins, resistant crops, vegetables, higher milk producing animals, and the list is endless**. (Verma A et *al* 2011).**

Based on applications, The main subfields of biotechnology are Green biotechnology is a biotechnology applied to agricultural processes ,Industrial biotechnology (also known as white biotechnology) is the practice of using cells to generate industrially useful products. It has been applied in variety of industrial processes in different ways, particularly in the use of biocatalysts in manufacturing processes. Medical Biotechnology or red biotechnology related to the involvement of engineering and technology principles to the domain of living or biological systems. **(Gupta V et al. 2016).** Blue biotechnology or marine biotechnology seeks to explore and use marine biodiversity as a source of new products, bioprospecting the

environment and using molecular biology and microbial ecology in marine organisms to obtain beneficial advances for humanity **(Mayara C et *al*.2018).**

3. HISTORY OF BIOTECHNOLOGY

Biotechnology is a field that has been evolving over the past few decades and is based on the application of biological processes and systems to create useful products and services. The term biotechnology was coined in 1919 by the Hungarian engineer, Karl Ereky. However, the history of biotechnology dates back to ancient times when people used fermentation to produce food and drink, such as beer, wine, and bread **(Bud. 1993; Carol Gigliotti .2009).**

In modern times, the development of biotechnology can be traced back to the mid-20th century when scientists began to use genetic engineering to manipulate organisms at the molecular level. One of the early breakthroughs was the discovery of the structure of DNA in 1953 by Watson and Crick, which laid the foundation for understanding the genetic code

In the 1970s, the first genetically engineered organism was created by Paul Berg, who combined DNA from a monkey virus with that of a bacterial virus. This breakthrough led to the development of recombinant DNA technology, which allows scientists to manipulate genes and create new organisms with specific traits

Since then, biotechnology has continued to advance rapidly, with new techniques such as gene editing, synthetic biology, and bioinformatics emerging in recent years. Biotechnology has had a significant impact on a wide range of fields, including medicine, agriculture, energy, and the environment.

In summary, here are examples of biotechnologies throughout history according to (Jain, et al., 2021):

Examples	Biotechnologies Throughout History
Agriculture	-The earliest form of biotechnology was agriculture, where plants were intentionally cultivated as living organisms for food and other purposes. This practice allowed early humans to transition from a hunter-gatherer lifestyle to a more settled, agricultural lifestyle, leading to the development of civilizations. -Agricultural technology has evolved greatly over time, with crop rotation being one of the earliest advancements in ancient Greece. Modern agricultural biotechnology has led to the creation of genetically modified organisms (GMOs), which are the result of manipulating the DNA of plants to enhance their desired traits.
Vaccinations	-The use of biotechnology in medicine can be traced back to the

	development of vaccination, which involves administering an inactive virus to a patient, allowing the immune system to learn how to recognize and fight off the virus in the future. -In the early 19th century, the first vaccine was developed to protect people from smallpox, demonstrating the potential of biotechnology to improve public health.
Fermentation	-Fermentation is an early biotechnology that has been utilized for centuries in the preparation of food and beverages such as bread and beer. -These processes rely on the use of living organisms, particularly yeast, to ferment the ingredients and create a desirable end product. The ancient Chinese (circa 7 BCE) and Egyptians (circa 4 BCE) were among the first to use fermentation techniques in food preparation.
Animal husbandry	-Domestication of animals, such as cattle, sheep, and goats, began over 10,000 years ago and was one of the earliest forms of biotechnology. Selective breeding techniques were used to produce animals with desirable traits, such as increased productivity and better disease resistance. -In the 20th century, advances in artificial insemination, embryo transfer, and genetic engineering have allowed for even more precise control over animal breeding and production.

4. IMPORTANCE OF BIOTECHNOLOGY

Biotechnology is a rapidly growing field of study that has emerged as a key driver of progress and innovation in various areas, including agriculture, medicine, and environmental science. Biotechnology involves the application of scientific and engineering principles to develop new products and processes based on living organisms, their parts, and their interactions with the environment.

One of the key areas where biotechnology has made a significant impact is in the development of new medicines and therapies. Nevertheless, the field has developed greatly over the past century in ways that interfere with the genetic makeup and biomolecular functions of living organisms. Molecular biology, bionics, chemistry, genomics, genetic engineering, informatics, and nanotechnology are just a few of the science and technological disciplines that are used in modern biotechnology **(Roque-Borda, 2022).** Consequently, Biotechnology has enabled the creation of new drugs and treatments for a variety of diseases that were previously untreatable, such as cancer and genetic disorders. Through the use of biotechnology techniques, scientists are able to develop targeted treatments that can be tailored to specific patients, leading to more effective outcomes and improved quality of life.

In addition to medicine, biotechnology is also playing a vital role in agriculture, where it is helping to increase crop yields and improve the nutritional value of food. Through the use of biotechnology, farmers can grow crops that are resistant to pests and diseases, and that

require less water and fertilizer. This not only benefits the environment, but also helps to ensure a reliable and sustainable food supply for an ever-growing global population.

Another important area where biotechnology is making a difference is in environmental science. Biotechnology is being used to develop new technologies for the production of renewable energy, such as biofuels, and to clean up contaminated sites. Biotechnology is also being used to study and protect biodiversity, by enabling scientists to better understand the genetics and behavior of organisms, and to develop new strategies for conservation. As the world faces numerous challenges in the coming decades, such as climate change and the emergence of new diseases, biotechnology is likely to play an increasingly important role in finding solutions to these problems. Therefore, it is essential for academic researchers and students to continue to explore and innovate in this field.

5. TYPES OF BIOTECHNOLOGY

Biotechnology is a diverse and rapidly evolving field that encompasses a wide range of technologies and applications. At its core, biotechnology involves the use of living organisms, or their components, to develop new products and processes that can benefit human health, agriculture, the environment, and many other areas. There are several different types of biotechnology, including medical biotechnology, agricultural biotechnology, industrial biotechnology, and environmental biotechnology. Medical biotechnology involves the use of biotechnology to develop new drugs, vaccines, and therapies for the treatment of diseases. Agricultural biotechnology focuses on developing new technologies for crop improvement and food production, such as genetically modified crops. Industrial biotechnology involves the use of biotechnology to develop new products and processes for industrial applications, such as the production of biofuels. Environmental biotechnology involves the use of biotechnology to address environmental challenges, such as pollution control and waste management.

Each type of biotechnology presents unique opportunities and challenges, and understanding these different types of biotechnology is essential for the development of new and innovative solutions to complex problems. Although, there are alternative ways to categorize biotechnology, the most common method is by using a color code. This system aims to facilitate the recall and organization of the various fields of biotechnology. Biotechnology encompasses numerous fields, each separated by a specific color that corresponds to a particular aspect of biotechnology.

As mentioned in Table (1), and based on frequent uses and applications, biotechnology is divided into sub disciplines that are color-coded **.**Thus, this color-coded system serves as an efficient tool for classifying and understanding the different areas of biotechnology **(Kafarski, 2012)**.

Table (1): Classification of Biotechnology According to Colors

Color	Area of activity
Red	Medicine and human health
Green	Processes improving agriculture
Blue	Marine biotechnology
Yellow	Food and nutrition
Grey	Environmental biotechnology
Gold	Bioinformatics, computer science
Brown	Biotechnology of dessert and dry regions
Violet	Law, ethics, philosophy
Dark	Bioterrorism, biological warfare
White	Industrial processes involving microorganisms

1. **Green biotechnology**: Any biotechnology used in the agricultural industry is referred to as "green biotechnology." One area of active research within the discipline is the genetic engineering of pest-resistant plants (in order to reduce the usage of chemical pesticides).
2. **White biotechnology**: Industrial biotechnology, also referred to as "industrial biotech," is another name for white biotechnology. Any biotechnology applied to industry is referred to by this phrase. To produce specialized chemicals or enzymes, for instance, certain firms use microbes **(Riberio, et *al*., 2015).**
3. **Blue biotechnology**: For a variety of industrial and commercial uses, blue biotechnology makes use of marine-based organisms. The creation of biofuel from photosynthetic algae is one instance.
4. **Dark Biotechnology**: Biological terrorism or biological weapons are examples of dark biotechnology. Examples include the creation of toxins using microorganisms and the genetic modification of viruses for use as weapons.
5. **Yellow biotechnology**: Any biotechnological applications in the food business fall under the umbrella of yellow biotechnology. It's interesting to note that many of these examples date back hundreds or even thousands of years, but they are still used today on a larger, more industrial level. Brewing beer, manufacturing cheese, and baking bread are a few examples.
6. **Violet Biotechnology**: The legal subset of biotechnology is known as violet biotechnology. The area focuses on ensuring the safe use of biotechnology as well as patent law and intellectual property rights.
7. **Red biotechnology**: Any biotechnology employed in medicine or pharmaceuticals is referred to as red biotechnology. One well-known use of red biotechnology is the synthesis of antibiotics from different mold species (or other microbes) **(Mayara, et *al*.2018).**
8. **Brown biotechnology**: This term describes biotechnology applications, such as the development of drought-resistant crops, in arid, drought-stricken areas.
9. **Bioinformatics:** It is also referred to as "computational biology" and "gold biotechnology." In a nutshell, bioinformatics uses computer methods to look for answers to biological problems.

10. **Gray biotechnology**: Any biotechnology utilized for environmental goals is referred to as "gray biotechnology." The practice of "bioremediation," which uses anaerobic bacteria to break down and remove harmful contaminants, is one typical example **(Mayara, et *al.*2018).**

6. MAIN APPLICATIONS OF BIOTECHNOLOGY

6.1 APPLICATIONS IN MEDICINE

Biotechnology has become an essential tool in the field of medicine and has led to significant advancements in healthcare. Here are some potential topics for a scientific paper on the application of biotechnology in medicine:

- **Gene Therapy:** Gene therapy is a technique that involves the insertion of genes into cells to treat or prevent disease. This can be achieved using a variety of methods, including viral vectors or non-viral methods such as electroporation. Some of the diseases that have been targeted using gene therapy include cystic fibrosis, muscular dystrophy, and some types of cancer**. (Ginn, S et *al*. 2018)** and **(Raper, S et *al*.2019).**
- **Recombinant Protein Production**: Biotechnology has enabled the large-scale production of recombinant proteins, which can be used as therapeutics. Recombinant proteins are produced by genetically modifying bacteria, yeast, or mammalian cells to express a specific protein. Examples of recombinant protein-based therapeutics include insulin for diabetes, growth hormone for growth disorders, and clotting factors for hemophilia. **(Walsh, G 2018) ; (Langer, E. S., et *al*. 2018).**
- **Genome Editing**: The ability to manipulate the genetic code has revolutionized medicine. Genome editing techniques such as CRISPR-Cas9 can be used to modify genes in cells or organisms, with potential applications in treating genetic disorders, cancer, and infectious diseases. **(Zhang, Yet *al* 2018 ; Slaymaker et al. 2019).**
- **Personalized Medicine:** Advances in biotechnology have paved the way for personalized medicine, which tailors treatment to an individual's unique genetic makeup. This can be achieved using techniques such as genetic testing and pharmacogenomics, which involves studying how an individual's genes affect their response to drugs.(**Hasin, Y.et *al*.2017; Delaney, S. K., & Haas, M. J. 2019).**
- **Stem Cell Therapy**: Stem cells have the potential to develop into any type of cell in the body, making them a valuable tool for treating diseases and injuries. Biotechnology has enabled the large-scale production of stem cells, as well as the ability to manipulate their properties for specific applications (**Trounson, A., & McDonald, C. 2015; Baghbaderani et al.2018).**

6.2 APPLICATIONS IN AGRICULTURE

Biotechnology has had a significant impact on agriculture, with a range of applications that have led to improvements in crop yields, disease resistance, and more sustainable farming practices. According to many researchers here are some of the main applications in the agricultural sector:

- **Genetically modified crops:** Genetically modified crops are plants that have been engineered to possess specific traits, such as resistance to pests, diseases, or herbicides. This technology has been widely adopted by farmers worldwide, and has been shown to have significant economic and environmental benefits. Some studies have found that GM crops can increase crop yields by up to 25%, reduce pesticide use by up to 37%, and decrease greenhouse gas emissions by up to 22% **(Klümper, W., & Qaim, M. 2014).**
- **Molecular breeding:** Molecular breeding involves using molecular markers to select for desirable traits in plants, such as disease resistance or drought tolerance. This technology has enabled breeders to develop new crop varieties more efficiently, with higher precision and greater speed **(Gupta, P et *a*l.2005; Varshney, et *al*.2019).**
- **Precision agriculture:** Precision agriculture involves using technologies such as GPS, sensors, and drones to monitor crop growth and optimize farming practices. This approach can lead to more efficient use of resources such as water and fertilizers, as well as higher yields and improved soil **health (Mueller, et al.2019 and Valdivia et al.2020).**
- **Plant biotechnology for stress tolerance:** Plant biotechnology can be used to develop crops that are more resistant to abiotic stresses such as drought, heat, and salinity. This can lead to improved crop yields in areas that are affected by these stressors **(Hasanuzzaman et *a*l.2013).**
- **The use of microbial inoculants**: Microbial inoculants are living microorganisms that are added to soil or seeds to enhance plant growth and health. These microorganisms can promote nutrient uptake, increase resistance to diseases and pests, and improve soil fertility **(Compant et *al*.2020 and Gouda, et *al* 2018).**

6.3 BIOTECHNOLOGY APPLICATIONS FOR ENVIRONMENT SOLUTIONS

Biotechnology applications have significant potential for addressing environmental challenges by providing innovative and sustainable solutions for various sectors such as agriculture, industry, and waste management.

- **Bioremediation:** is a process that uses living organisms to clean up environmental pollution. It is a sustainable and cost-effective approach that can be customized to treat specific contaminants in a given environment. Bioremediation can be carried out in situ, reducing the cost and environmental impact associated with the transportation of hazardous waste. Overall, bioremediation is an important tool of environmental biotechnology that has the potential to be used on a large scale to address a wide range of environmental problems **(Das, N., & Chandran, P. 2011 and Glick, B. R. (2010) ; Singh, A et al.2005; Zaidi, S et al.2006).**
- **Phytoremediation** : is an environmentally friendly and sustainable biotechnology tool that uses plants to remove, degrade, or immobilize pollutants from contaminated soil, water, or air It can be used for the treatment of various contaminants such as heavy metals, organic pollutants, pesticides, and explosives. The process involves the use of specific plant species that can tolerate high levels of contaminants and accumulate them in their tissues. The contaminants can then be removed by harvesting the plants or allowing them to degrade the contaminants naturally. (**Shahid et al.2017; Pandey, V., & Srivastava, P. 2017 and Baker, A. J. M., & Reeves, R. D. 2018).**

- **Biogas production**: Biogas technology is an important tool of biotechnology because it can help to reduce greenhouse gas emissions, generate renewable energy, and provide economic benefits to farmers and other stakeholders. Biogas is produced through a process called anaerobic digestion, which involves the breakdown of organic matter by bacteria in the absence of oxygen. The end product of this process is a gas mixture containing methane, carbon dioxide, and other gases, which can be used as fuel for electricity generation, heating, and cooking. Biogas technology has several advantages over other renewable energy sources, including its ability to utilize various types of organic waste, its potential to reduce greenhouse gas emissions, and its ability to provide a reliable source of energy in rural areas **(Demirbas.2010 ; Fernández-López, M., & Pérez, M. 2016) and Khan et al.2019).**

6.4. OTHER APPLICATIONS

Biotechnology is a rapidly advancing field with applications that extend beyond its traditional domains of environment, medicine, and agriculture. One such application is industrial biotechnology, which utilizes enzymes, microorganisms, and other biological agents to produce chemicals, fuels, and materials in a more sustainable and efficient manner **(Kumar, A., & Sharma, S. 2017).**

Biotechnology can also be used to enhance food production and quality, such as the development of genetically modified crops, and to improve food processing and preservation **(Ramessar, K et al.2008).** In addition, biotechnology can help address energy challenges by developing renewable sources of energy, such as biofuels and biogas, which can reduce dependence on fossil fuels and mitigate climate change **(Peralta-Yahya et al.2012).** Biotechnology can also be applied in forensic science to identify individuals through DNA analysis and to detect and analyze biological evidence (**Butler, J. M. 2006).**

Finally, the combination of biotechnology with nanotechnology has led to the development of novel materials and devices with unique properties and functions, such as drug delivery systems and biosensors (**Zhang, Y., & Wang, Z. 2019).** These applications demonstrate the wide range of potential uses for biotechnology in various fields, and highlight the importance of continued research and innovation in this area.

CONCLUSION AND PROSPECTS

Biotechnology has had a remarkable impact on human life by revolutionizing healthcare, agriculture, industry, and environmental management. However, the future prospects of biotechnology are even more promising. The integration of biotechnology and information technology is driving the development of personalized medicine, where treatments are tailored to the individual patient's genetic makeup, leading to better health outcomes. Gene editing and synthetic biology advancements offer the potential to create novel and more effective therapies for diseases, while also improving crop yields and sustainability. Furthermore, biotechnology has the potential to contribute to the development of sustainable biofuels, bioplastics, and other renewable resources, reducing reliance on fossil fuels and mitigating environmental pollution. The continued growth and development of biotechnology hold great promise for solving some of the most pressing challenges facing humanity in the 21st century. From developing innovative diagnostic tools and therapies for diseases to optimizing agricultural productivity and sustainability, biotechnology will play a vital role in shaping the future of our planet. The potential for further advancements is

significant, and the continued development of biotechnology could hold the key to improving the quality of life for people around the world.

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