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Biotechnology and its Applications

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Abstract:

Biotechnology is the technological application which utilizes biological entities, living organism or biological derivatives. The origin of biotechnology was not novel, and it arose in ancient age. The ancient Egypt and China were the countries that used biotechnology in the form of food fermentation. The concept of biotechnology bound in wide range of procedures for modifying living organisms based on the need of human activities. It can be traced many centuries back, when wine making, production of vinegar and distilling were important human skills. The history of biotechnology as an industry begins in the early 19th century. Thousands of years back, biotechnology was used by mankind in agriculture, food production and medicine. Modern technology of biotechnology was upgraded by using genetic engineering, cell and tissue culture techniques. The new era of modern biotechnology came through the discovery of genes made of DNA. Manipulating of living things have been done by humans since the ancient age. Modern biotechnology recent developments include genetically modified plants and animals, genetic engineering and cell fusion.

Key Words: Biotechnology, application, genetic engineering, DNA

Introduction

Biotechnology is the broad area of biology involving living system and organisms to develop or make products or any technological application that uses biological systems, living organisms or derivatives thereof to make or modify products or processes for specific use. Depending on the tools and applications, it often overlaps with the related fields of molecular biology, bioengineering, biomedical engineering, biomanufacturing, molecular engineering etc[1]

For thousands of years, mankind has used biotechnology in agriculture, food production and medicine. The term is largely believed to have beencoined in 1919 by Hungarian engineer Kàroly Ereky. In the late 20thand early 21st centuries, biotechnology has expanded to include new and diverse, sciences such as genomics, recombinant gene techniques, applied immunology and development of pharmaceutical therapies and diagnostic test [2].

The wide concept of biotechnology encompasses a wide range of procedures for modifying living organisms according to human purposes, going back to domestication of animals, cultivation of plants and improvements to these through breeding programs that employ artificial selection and hybridization. Modernusage also includes genetic engineering as well as cell and tissue culture technologies. The American Chemical Society defines biotechnology as the application of biological organism, systems or processes by various industries to learning about the science of life and the improvement of the value of materials and organism such as pharmaceutical, crops and livestock. European Federation of Biotechnology also defined biotechnology as the integration of natural science and organisms, cells, parts thereof, and molecular analogues for products and services. Biotechnology is based on the basic biological sciences (e.g molecular biology, biochemistry, cell biology, embryology, genetics, microbiology) and conversely provides methods to support and perform basic research in biology [3].

Biotechnology is the research and development in the laboratory using bioinformatics for exploration, extraction, exploitation and

production from any living organism and any source of biomass by means of biochemical engineering where value added products could be planned (reproduced by biosynthesis), forecasted, formulated, developed, manufactured and marketed for the purpose of sustainable operations (for the return from bottomless initial investment on R&D) and gained durable patients rights (for exclusive rights for sales, and prior to this to receive national and international approval for the results on animals experiment and human experiment especially on the pharmaceutical branch of Biotechnology to prevent any undetected side effects or safety concerns by using the products. The utilization of biological processes, organism or system to produce products that are anticipated to improve human lives is termed biotechnology[4]

History Of Biotechnology

Although not normally what first comes to mind, many forms of human- derived agriculture clearly fit the broad definition of "utilizing a biotechnological system to make products".Indeed, the cultivation of plants may be viewed as the earliest biotechnological enterprise. Agriculture has been theorized to have become the dominant way of producing food since the Neolithic Revolution[5].

Through early biotechnology, earliest farmers selected and bored the best suited crops, having the highest yields, to produce enough food to support a growing population. As crops and fields became increasingly large and difficult to maintain, it was discovered that specific organism and their by-products could effectively, fertilize, restore nitrogen and control pest. Throughout the history of agriculture, farmers have inadvertently altered the genetic of their crops through introducing them to new environments and breeding them with other plants- one of the first forms of biotechnology. Biotechnology has also led to the development of antibiotics. In 1928, Alexander Fleming discovered the Mold Penicillium. His work led to the purification of the antibiotic compound formed by the mold by Howard Florey, Ernst Boris Chain and Norman Heatley – to form what we know today as penicillin. In 1940 Penicillin became available for medicinal use to treat bacterial infection in humans [6]

TYPES OF BIOTECHNOLOGY

(1) MEDICAL BIOTECHNOLOGY

Medical Biotechnology is the use of living cells and other cell materials for the purpose of improving human health.Essentially, it is used for finding cures as well as getting rid off and preventing diseases. The science involved includes the use of these tools for the purpose of research to find different or more efficient ways of improving human health, understanding pathogen, and the human cell biology.

Here, the technique is used to produce pharmaceutical drugs as well as other chemicals to combat diseases.It involves the study of bacteria, plant and animals cells to first understand the way they function at a fundamental level.

Also, it makes use of DNA (Deoxyribonucleic acid) to manipulate the genetic makeup of cells to increase the production of beneficial characteristics that humans might find useful such as the production of insulin. The field usually leads to the development of new drugs and treatments, novel to the field.[7]

Examples of Medical Biotechnology are: a. Vaccines production b. Antibiotics production.

(a) Vaccines production:

Vaccines are chemicals that stimulate the body's immune system to better fight pathogens when they attack the body. They achieve this by inserting attenuated versions of the disease into the bloodstream. This causes the body to react as it was under attack from the non-attenuated version of the disease. The body combats the weakened pathogen and through the process takes note of the cell structure of pathogen and has some cell remember.The disease store away the information within the body when the individual is exposed to the actual disease and the body immediately recognizes it and quickly forms a defense against it[8].

The attenuated disease pathogens are extracted using biotechnological techniques such as growing the antigenic proteins in genetically engineered crops. An example is the development of an anti-lymphoma vaccine using genetically engineered tobacco plants made to exhibit RNA (Riboxynucleic Acid) from malignant B- cells[9].

(b) Antibiotics production

Strides have been made in the development of antibiotics that combat pathogens for humans. Many plants are grown and genetically engineered to produce the antibodies. This method is more cost effective than using cells or extracting these antibodies from animals as the plants can produce these antibodies in large quantities[10[.

2. AGRICULTURAL BIOTECHNOLOGY

Agricultural biotechnology focuses on developing genetically modified plants for the purpose of increasing crop yields or introducing characteristics to those plants that provide them with an advantage of growing in regions that place some kind of stress factor on the plant namely weather and pests.Examples include: (a) pest resistant crops (b) plant and animal breeding.

a. **Pest resistant Crops**:

Biotechnology has provided techniques for the creation of crops that express anti-pest characteristics naturally, making them very resistant to pests as opposed to having to keep dusting them and spraying them with pesticides.Example is fungus Bacillus thuringiensis genes being transferred to crops. This is because fungus produces a protein (Bt) which is effective against pest such as European corn borer; so, the scientist identified the gene causing Bt protein to express the fungus and transferred it to corn.The corn then produces the protein toxin naturally, lowering the cost of production by eliminating the cost of dusting the crop with pesticide. This involves the animals with the most desirable the resulting offspring would also express these traits. Desirable characteristics include: lager animals, animals more resistant to disease and more domicile animals, all geared to making the farming process more profitable. This practice has transferred to the molecular level with the same purpose. Different traits are selected among the animals and once the genetic markers have been pointed out, animals and plants with those traits are selected and bred for those traits to be transferred. A genomic understanding of those traits informs the decision on whether the desired traits will express or get lost as recessive traits.[11]

This information provides the basis for making information decisions enhancing the capability of the scientists to predict the expression of those genes. An example is its use in flower production where traits such as colour and smell potency are enhanced[12]

On the other hand, biotechnology can be classified based on some common features of the final purpose. Below are some of the main areas of biotechnology using a colour classification.

1. Red Biotechnology

Red Biotechnology (Biopharma) brings together all those Biotechnology uses connected to medicine and veterinary products. Red biotechnology includes producing vaccines and antibiotics, developing new drugs, molecular diagnostic techniques, regenerative therapies and the development of genetic engineering to cure diseases through genetic manipulation[13].

2. White Biotechnology

White Biotechnology relates to industrial Biotech. White biotechnology pays special attention to designing low resource–consuming processes and products, making them more energy efficient and less polluting than traditional ones.An example of white biotechnology is the use of microorganisms in chemical production, the design and production of new plastics/textiles and the development of new sustainable energy sources such as bio-fuels.

3. Yellow Biotechnology

Yellow biotechnology has been used to refer to the use of biotechnology in food production, for example in making wine, cheese, and beer by fermentation.

4. Grey Biotechnology

Grey Biotechnology refers to environmental applications and is focused on the maintenance of biodiversity and the removal of pollutants/contaminants using microorganisms and plants to isolate and dispose different substances such as heavy metals and hydrocarbons. An example is the carlow based SME MicroGen Biotech which is helping to clean industrially polluted land in china.

5. Green Biotechnology

Green Biotechnology is focused on agriculture. Green biotechnological approaches and applications include creating new plant varieties of agricultural interest producing biofertilizers and biopesticides.This area of biotechnology is based exclusively on transgenic (genetic modification) that isthey have an extra gene(s) inserted into their DNA. The extra gene may come from the same species or from a different species. One of the interesting developments is that plant varieties are able to act as bio-factories and produce substance of medical, biomedical or industrial interest in quantities easy to be isolated and purified to grow ebola vaccine.

6. Blue biotechnology:

Blue biotechnology is based on the exploitation of marine resources to create products and applications of industrial interest. Taking into account that the sea presents the greatest biodiversity, there is potentially a huge range of sectors to benefit from use of this kind of biotechnology. Example is the use of wound dressings coated with Chitosan (Chitosan is a sugar that is typically derived from shrimp and crab shells)[14].

APPLICATIONS OF BIOTECHNOLOGY

Key applications of biotechnology includes:

- DNA Profiling
- DNA Cloning
- Transgenesis
- Genome Analysis
- Stem Cells and Tissue Engineering
- Xenotransplantation

DNA profiling or **DNA fingerprinting** is the process of determining an individual's **DNA** characteristics, which are as unique as fingerprints. It is the process which a specific DNA pattern, called a profile, is obtained from a person or sample of bodily tissue[15]

Even though we are all unique, most of our DNA is actually identical to other people's DNA. However, specific regions vary highly between people. These regions are called polymorphic. Differences in these variable regions between people are known as polymorphisms. Each of us inherits a unique combination of polymorphisms from our parents. DNA polymorphisms can be analysed to give a DNA profile[16]

Human DNA profiles can be used to identify the origin of a DNA sample at a crime scene or test for parentage.

DNA profiling is used to:

- identify the probable origin of a body fluid sample associated with a crime or crime scene
- reveal family relationships
- identify disaster victims,

DNA Cloning

DNA cloning, is the production of multiple identical copies of a DNA fragment, is responsible for all sorts of things, such as pest-resistant plants, bacteria used for toxic waste cleanup. **It** is a molecular biology technique that makes many identical copies of a piece of **DNA**, such as a **gene**. In a typical **cloning** experiment, a target **gene** is inserted into a circular piece of **DNA** called a plasmid.

Transgenesis

This is the process of introducing a gene from one organism into the genome of another organism. The aim is that the resulting **transgenic** organism will express the gene and exhibit some new characteristic. Transgenesis may be used to generate a new breed of animals that is genetically different thus contributing to genetic diversity. In some cases the transgenic protein may have side effects on the genetically modified animal. This could have a positive or negative impact on the animals health. The implications are specific to each and depend on the gene being added (or removed), the organism being modified and it's environment.

Genome Analysis

This is the identification, measurement or comparison of **genomic** characteristics like DNA sequence, structural variation, gene expression, or regulatory and functional element annotation at a **genomic** scale. Methods for genomic analysis require mainly microarray hybridization and bioinformatics.

Stem Cell

A stem cell is a cell with the unique ability to develop into specialised cell types in the body. In the future they may be used to replace cells and tissues that have been damaged or lost due to disease. It is an undifferentiated cell of a multicellular organism

which is capable of giving rise to indefinitely more cells of the same type, and from which certain other kinds of cell arise by differentiation. They have the remarkable potential to develop into many different cell types in the body during early life and growth.

Xenotransplantation

Is the transplanting of cells, tissue or organs from one species into another. It is the process of grafting or transplanting organs or tissues between members of different species. Xenotransplantation is any procedure that involves the transplantation, implantation or infusion into a human recipient of either (a) live cells, tissues, or organs from a nonhuman animal source, or (b) human body fluids, cells, tissues or organs that have had *ex vivo* contact with live nonhuman animal cells, tissues or organs. The development ofxenotransplantation is, in part, driven by the fact that the demand forhuman organs for clinical transplantation far exceeds the supply.

Biotechnology can also be applied in other areas viz: Medicine, Agriculture, Industrial ,Environmental etc[17]

APPLICATION OF BIOTECHNOLOGY IN MEDICINE

In medicine, modern Biotechnology has many applications in areas such as pharmaceutical drugs discoveries and production, pharmacogenomics, and genetic testing (or genetic screening).

PHARMACOGENOMICS

Pharmacogenomics is the technology that analyses how genetic makeup affects an individual's response to drugs [1] Researchers in the field investigate the influence of genetic variation on drug responsesin patients by correlating gene expression or single-nucleotide polymorphisms with a drug's efficacy or toxicity [18].The purpose of pharmacogenomics is to develop rational means to optimize drugs therapy, with respect to patients genotype to ensure maximum efficacy with minimal adverse effects([19]. Such approaches promise the advent of "personalized medicine", in which drugs and drug combinations are optimized for each individual's unique genetic makeup [20]. Biotechnology has contributed to the discovery and manufacturing of traditional small molecule pharmaceutical drugs as well as drugs that are the products of biotechnology – biopharmaceutics. Modern biotechnology can be used to manufacture existing medicines relatively easily and cheaply.

The first genetically engineered products are medicines designed to treat human diseases. To cite one example, 1978 Genentech developed synthetic humanized insulin by joining its gene with a plasmid vector inserted into the bacterium Escherichia coli.Insulin, widely used for the treatment of diabetes, was previously extracted from the pancreas of abattoir animals (cattle or pigs). The genetically engineered bacteria are able to produce large quantities of synthetic human insulin at relatively low cost [21]. Biotechnology has also enabled emerging therapeutics like gene therapy. The application of biotechnology to basic science (example is through the Human Genome Project) has also dramatically improved our understanding of biology and as our scientific knowledge of normal and disease biology has increased, our ability to develop new medicines to treat previously untreatable diseases has increased as well.Genetic testing allows the genetic diagnosis of vulnerabilities to inherited diseases and can also be used to determine a child's parentage (genetic father and mother) or in general a person's ancestry. In addition to studying chromosomes to the level of individual genes, genetic testing in a broader sense includes biochemical tests for the possible presence of genetic disease or mutant forms of genes associated with increased risk of developing genetic disorders.

Genetic testing identifies changes in chromosomes, genes or proteins. Most of the time, testing is used to find changes that are associated with inherited disorders. The result of genetic test can confirm or rule out a suspected genetic condition or help determine a person's chance of developing or passing on genetic disorders. As of 2011, several hundred genetic tests were in use. Since genetic testing may open up ethical or psychological problems, genetic testing is often accompanied by genetic counseling.

AGRICULTURE

Genetically modified crops ("GM Crops") are plants used in agriculture, the DNA of which has been modified with genetic engineering techniques.In most cases, the main aim is to introduce a new trait that does not occur naturally in the species. Biotechnology firms can contribute to future food security by improving the nutrition and viability of urban agriculture[22].

Furthermore, the protection of intellectual property rights encourages private sector investment in agrobiotechnology. For example, in Illinois FARM Illinois (Food and Agriculture Roadmap for Illinois) is an initiative to develop and coordinate farmers, industry, research institutions, government and non-profits in pursuit of food and agricultural innovation. In addition, the Illinois Biotechnology IndustryOrganization (iBIO) is a life science industry association with more than 500 life Science Companies, Universities, academic institutions, service providers and others as members. The association describes its members as "dedicated to making Illinois and the surrounding Midwest one of the world's top life sciences centers [23]. Examples in food crops include resistance to certain pest, diseases, stressful environmental conditions, resistance to chemical treatments (example, resistance to herbicide [25[,reduction of spoilage,[26] or improving the nutrient profile of the crop. Examples in non-food crops include production of pharmaceutical agents,[27] biofuels [28] and other industrially useful goods [29]as well as for bioremediation [30]

Genetically modified foods are foods produced from organisms that have had specific changes introduced into their DNA with the methods of genetic engineering. These techniques have allowed for the introduction of new crop traits as well as a far greater control over a food's genetic structure than previously afforded by methodssuch as selective breeding and mutation breeding.Commercial sale of genetically modified foods began in 1994, when Calgene first marketed its Flavr Savr delayed ripening tomato [31]. To date, most genetic modification of foods have primarily focused on cash crops in high demand by farmers such as soybean, corn, conola and cotton seed oil. These have been engineered for resistance to pathogens and herbicides and better nutrient profiles. GM livestock have also been experimentally developed; in November 2013 none were available in the market but in 2015, the FDA approved the first GM Salmon for commercial production and consumption.

GM crops also provide a number of ecological benefits, if not used in excess [32].However, opponent have objected to GM crops per se on several grounds, including environmental concerns, whether food produced from GM crop is safe, whether GM crops are needed to address the world's food needs, and economic concerns raised by the facts these organism are subject to intellectual property law.

INDUSTRIAL

Industrial biotechnology (white biotechnology in Europe) is the application of biotechnology for industrial purposes including industrial fermentation. It includes the practice of using cells such as micro organism or components of cells like enzymes to generate industrially useful productsin sectors such aschemical, food and feed, detergents paper and pulp, textiles and biofuels. In the current decades, significant progress has been done in creating genetically modified organisms (GMOs) that enhance the diversity of applications and economic viability of industrial biotechnology. By using renewable raw materials to produce a variety of chemicals and fuels, industrial biotechnology is actively advancing towards lowering greenhouse gas emissions and moving away from a petrochemical – based economy.

ENVIRONMENTAL

The environment can be affected by biotechnologies, both positively and adversely. Vallero and others have argued that the difference between beneficial biotechnology (example, bioremediation is to clean up an oil spill or hazard chemical leak) versus the adverse effect stemming from biotechnological enterprises (example, flow of genetic materials from transgenic organisms into wild strains) can be seen as applications and implications respectively [33]. Cleaning up environmental wastes is an example of an application of environmental biotechnology, whereas loss of biodiversity or loss of containment of a harmful microbe is examples of environmental implications of biotechnology.

ADVANTAGES OF BIOTECHNOLOGY IN MEDICINE

Biotechnology allows the development and production of new substances that were previously beyond the capacity of traditional technologies. These include the design and production of new drugs with greater potency and specificity and consequently fewer side effects. One example of this is the treatment for multiple sclerosis.

Biotechnology offers a greater control over the manufacturing process, allowing significant reduction in risks of contamination through infectious pathogens. An example is the blood products used to treat haemophilia.

Biotechnology offers better product- targeting for specific diseases and patients groups, through the use of innovative technologies, in particular genetics. Examples include treatments for rare diseases and cancers. Some products are not naturally created in sufficient quantities for therapeutic purposes. Biotechnology makes large scale production of existing substance possible. Example is insulin in the treatment of diabetes.

ADVANTAGES OF BIOTECHNOLOGY IN AGRICULTURE

The advent ofBiotechnology has benefited fields such as agriculture, animals husbandry etc. in agriculture Biotechnology, genetic engineering has enabled the production of crops that are able to grow in non-ideal soil or dry conditions. These genetically modified or transgenic crops are of higher quality and higher yield and increased shelf life. In addition, they have been engineered to be resistant to pests which allow farmers to use less pesticide.

NEGATIVE IMPACTS OF BIOTECHNOLOGY

Biotechnology has indeed done a lot of good for the world, but it has disadvantages and there are some concerns about its potentials negative impacts. In agriculture, there are concerns that genetically modified crops may transfer genetic material into natural unmodified plants. For instance, a crop that is herbicide resistant may transfer some of its traits to a weed which would result in herbicide resistant weed.Another concern about agricultural biotechnology centers on the uncertainty of genetically modified crops long-term biological viability[34]

IMPACT ON PRODUCTION AND GLOBAL MARKET

As a result of fast growth, pest resistance and hardiness of transgenic crops, the yield of such crops is typically higher than those of conventional crops. Yet, some economists are concerned that overproduction due to transgenic crops may result in effect such as market instability, reduced export income, fewer product varieties and even unemployment. Depressed economies may also be unable to take advantage of the potential benefits of agricultural biotechnology due to global overproduction. The asymmetrical availability of these crops also raises question about the potential for discriminatory exploitation [23]

IMPACT OF BIOTECHNOLOGY ON NATURE, BIODIVERSITY AND THE ECOSYSTEM

The long-term consequences of the genetic alteration of various organisms from bacteria in the pharmaceutical industry to the animals in biological research to the plants in agriculture are still unknown. Genetically modified organisms may also escape into the wild, especially transgenic microorganisms, and these events may upset the balance of the ecosystem in nature. This may cause a decrease in the biodiversity, also known as the variety of organisms [31]

POTENTIAL RISK OF BIOTECHNOLOGY ON HUMAN HEALTH

1. Genetically modified food may produce new proteins and it may act as new allergen and can induce allergic reactions in humans. Scientist cannot regulate the site of insertion of genes in the plant genome and this will induce new allergen in food chain.
2. Agricultural biotechnological technique like genetic engineering uses antibiotic resistant gene as markers and consumption of food products which have these antibiotic resistant genes may reduce the effectiveness of antibiotics. This also has the danger of transferring this antibiotic resistant gene to human pathogens and makes them antibiotic resistant.
3. Addition of genetic material by genetic engineering may interact with the pathways involved in the production of toxic substances produces by the plant which are used to preserve motionless organisms for predators.
4. Biotechnology may increase the contamination of soil and plants by heavy metals, by adding one or more new genes to plants.
5. This technology may induce health risk to humans as a result of proteins produced by newly added genes to the plants. It may increase the environment with toxic fungi.

POTENTIAL RISK OF BIOTECHNOLOGY IN THE ENVIRONMENT

1. Biotechnology increase herbicide resistant weeds.
2. Genetically modify plants produced using genetic engineering may transfer new genes into wild herbs, pests.
3. Plants produced using agricultural Biotechnological techniques may poison wildlife by producing toxic proteins.
4. Biotechnology may create new types of microorganisms like viruses and bacteria.

CONCLUSION

Biotechnology is a complement and not a substitute. For many areas of conventional agricultural research, it offers a range of tools to improve our understanding and management of genetic resources for food and agriculture. These tools are already making a contribution to breeding and conservation programmes and to facilitating the diagnosis, treatment and prevention of plant and animal disease. The application of biotechnology provides the researchers with new knowledge and tools that make the job more efficient and effective. Therefore, biotechnology- based research programmes can be seen as more precise extension of conventional approaches. At the same time, genetic engineering can be seen as a dramatic departure from conventional breeding because it gives scientists power to move genetic material between organisms that could be bred through classic means.

Agricultural biotechnology is cross-sectional and interdisciplinary.Most of the molecular techniques and their applications are common across all sectors of food and agriculture, but biotechnology cannot stand on its own. Genetic engineering in crops, for example, cannot proceed without knowledge derived from genomics and it is of little practical use in the absence of an effective plant- breeding programme. Biotechnology should be part of comprehensive, integrated agricultural research programme.

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