The benefits and risks of using genetic engineering in medical applications

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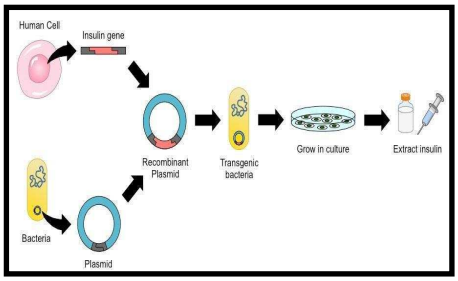
Abstract

Genetic engineering is a process that uses laboratory-based technologies to change the DNA of an organism. This may involve changing a single base pair (A-T or C-G), deleting a region of DNA or adding a new segment of DNA. At present, this method is used widely in medicine, industry and agriculture. So, it plays an important role in society. The purpose of this article is mention to the benefits and risks of using genetic engineering in various ways including medicine and food production. In addition, it demonstrates the process of genetic engineering such as insulin production. Not only this mention about history development of genetic engineering but also its use in the future. Although using genetic engineering provides many advantages, it is concerned with medical ethics and the development of cancer. Therefore, one should consider both pros and cons by weighing whether it is valuable to use this method before reaching the last decision.

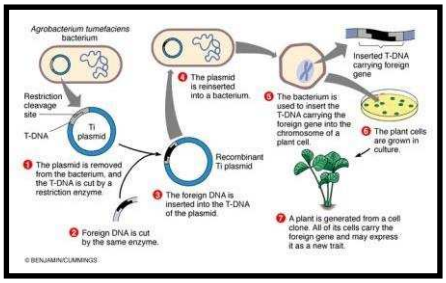
Keywords: genetic engineering, insulin production, GMO food, vaccine production, cancer, covid-19

Introduction

Genetic engineering (genetic modification) is a process that uses laboratory-based technologies to change the DNA makeup of an organism. This may involve altering a single base pair (A-T or C-G), deleting a region of DNA or adding a new segment of DNA[1]. For instance, genetic engineering may involve adding a gene from one species to an organism from a different species to produce a desired characteristic. The term "**genetic engineering**" is generally used to refer to methods of recombinant DNA technology that have led to the production of medically important products, including human insulin, human growth hormone, and hepatitis B vaccine, as well as to the development of genetically modified organisms such as disease-resistant plants [2]. In research and industry, genetic engineering has been applied to the production of cancer therapies, brewing yeasts, genetically modified plants and livestock [1]. Genetic engineering is composed of three steps. These are (1) The isolation of DNA fragments from a donor organism (2) The insertion of an isolated donor DNA fragment into a vector and (3) The growth of a recombinant vector in an appropriate host [3]. Genetic engineering is considered to become an essential method for curing patients because it allows scientists to choose one specific gene to implant and avoid selecting undesirable genes. Moreover, genetic engineering helps the process quickly, therefore it saves time and produces many products with desirable traits [4]. However, genetic engineering has both advantages and disadvantages to consider before treating patients and it is related to medical ethics [5].



picture1: The process of genetic engineering in plants[5].

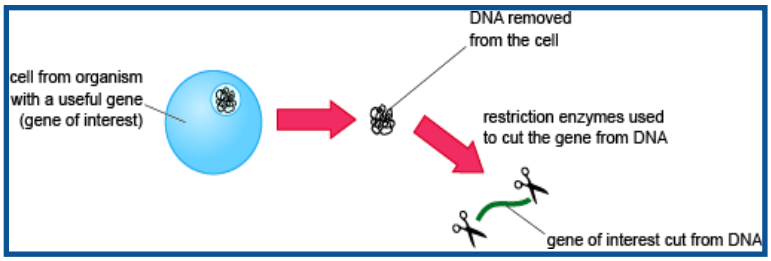


picture 2: the process of insulin production [6].

The step of genetic engineering

Genetic engineering is a difficult task, it requires complex machinery and innovative minds. There are numerous steps in the process of genetic modification. Scientists have to follow a step by step to successfully alter the DNA of an organism[6].

1. A useful gene (gene of interest) that has desirable traits is selected and cut from the DNA of one organism with a specific enzyme called " restriction enzyme".This enzyme breaks bonds between nucleotides [7].



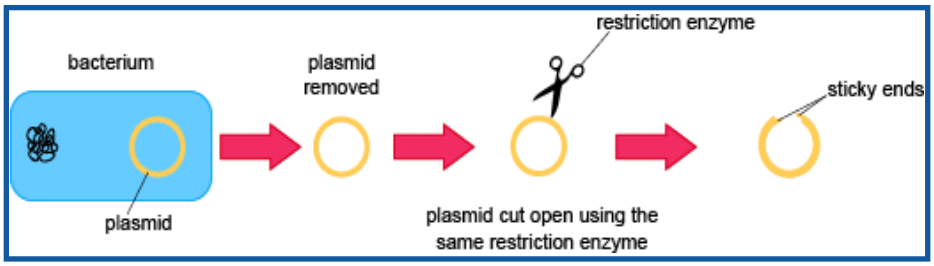
picture 3: removing DNA using restriction enzyme [7].

2. Restriction enzymes cut the DNA in a staggered way leaving short sections of single-stranded DNA at each end of the gene. These sections of single-stranded DNA are called "sticky ends" [7].

picture 4: the formation of sticky end [7].

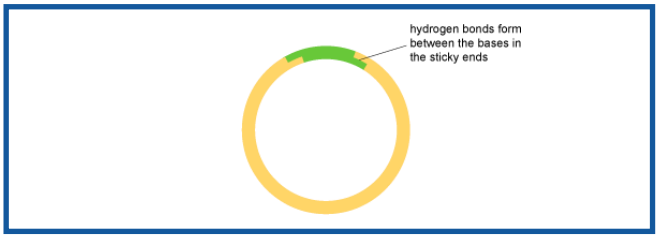
3. The bacterial plasmid DNA is cut open using the same restriction enzyme. The cut ends of the plasmid also have sticky ends.

The reason for using the same restriction enzyme is so that the sticky ends on the plasmid will have a short sequence of bases that are complementary to those on the end of the useful gene [7].



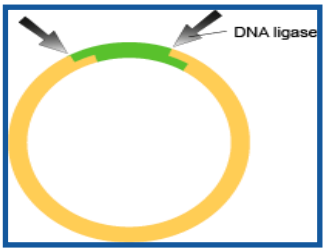
picture 5: removing the plasmid and cutting with restriction enzyme [7].

4. The useful gene and the plasmid DNA are mixed and the gene is inserted into the plasmid. Hydrogen bonds form between the complementary bases in the sticky ends of the plasmid and the useful gene [8].



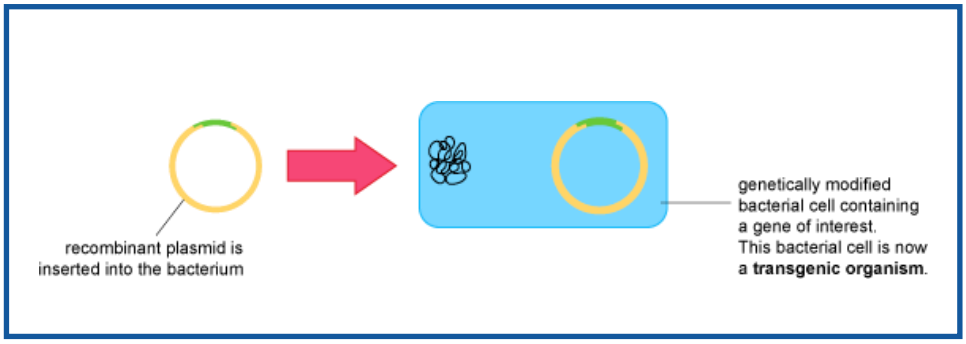
picture 6: hydrogen bond [8]

5. The enzyme DNA ligase is used to join the plasmid DNA and the useful gene together. The ligase joins the end nucleotides of the useful gene to the end nucleotides of the plasmid [8].



picture 7: The plasmid is now called a recombinant plasmid. It is a plasmid that has been altered and now has DNA from more than one source [8].

6. The recombinant plasmid is then inserted into a bacterial cell. The plasmid acts as a vector, carrying the gene into the bacterial cell.



picture 8: The bacterial cell is now a GMO. It can be cultured by cloning and the cell can use the gene that has been inserted into it to make a protein [8].

History development of genetic engineering

The ideas of genetic engineering were initially induced during the 1960s. Since the early 1990s, many scientists have discovered treatments for genetic diseases and cancers by using viral vectors. Although a variety of methods have been performed, it has been difficult to target cells. Recently, genetic engineering has become the advanced method for curing specific locations of the cell. In 1968, Rogers et al. indicated that foreign genetic materials could be transferred into cells by viruses. The Shope papillomavirus was transduced into two patients with genetic arginase deficiency. According to Rogers et al hypothesis revealed that this gene therapy produced little improvement in the arginase level of patients. Sequencing of the Shope papilloma virus demonstrated that the virus genome did not contain an arginase gene. This was the first experiment that caused concerns among people about the risks and ethics [9].In addition, Werner Arber discovered the concept of a restriction enzyme by

noticing bacteriophage-resistant bacterial cells [10]. This might express a specific enzyme that degrades only invading bacteriophage DNA, but not their own DNA. Arber hypothesized that bacterial cells might express two types of enzymes: a restriction enzyme that recognizes and cuts up the foreign bacteriophage DNA and a modification enzyme that recognizes and modifies the bacterial DNA to protect it from the DNA-degrading activity of its very own restriction enzyme. This method of cutting a DNA molecule into smaller pieces is called a" restriction enzyme digest", and it quickly became a powerful tool for generating physical maps of a multitude of genomes [11]. In 1972, Friedman et al. proposed ethical standards for the clinical application of gene therapy to prevent premature application in humans. However, in 1980, genetic engineering was unethically performed in patients with thalassemia without the approval of the institutional review board. Moreover, in the same period, Cohen discovered plasmids that reproduce the functioning part of the cell's DNA. Actually, Boyer and Cohen were the first successful genetic engineering researchers, however, their work was only the beginning of that field of research [12]. The gene therapy report of the President's Commission in the United States, Splicing Life, emphasised the difference between somatic and germline genome editing in humans and medical treatment and non-medical enhancement [13].

The benefits of genetic engineering

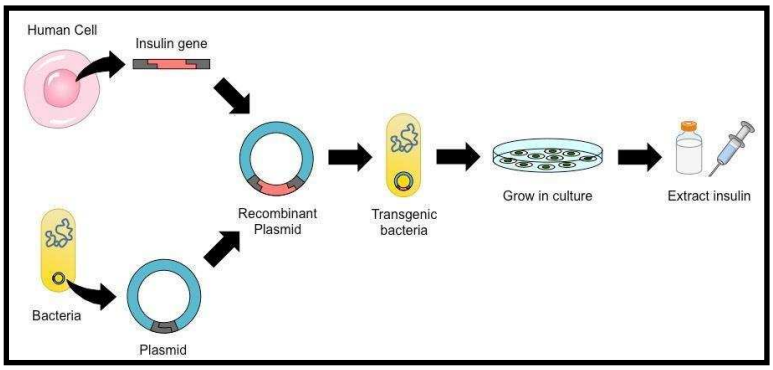
Human insulin production

Insulin is a protein that helps regulate the level of sugar in the blood. Human insulin produced by recombinant DNA is the first healthcare product derived from this advanced technology. Normally, insulin is produced by the pancreas, however, the patient who suffers from type 1 diabetes has a problem with insulin production, and therefore that patient lacks insulin. So, the patient who has diabetes type 1 has to inject insulin regularly in order to control the level of sugar in the blood. Genetic engineering has been used to produce a type of insulin that is similar to our body from yeast and bacteria [14].

1. Remove a plasmid from a desirable bacteria and cut a plasmid with restriction enzymes
2. Cut the plasmid open with restriction enzymes
3. Locate and remove the human insulin gene with the same restriction enzymes
4. The DNA is combined with the plasmid by using DNA ligase
5. Bacteria are then incubated with new recombinant plasmid
6. Bacteria will take up the plasmid and start to produce insulin

Advantages of genetically engineered insulin

- Not limited by the slaughter of animals.
- Large quantities can be made quickly.
- No risk of transferring infections.
- More effective at treating diabetes as animal insulin is different to human insulin.
- No ethical issues concerning the use of animals.



picture 9: The process of insulin production [15].

Genetic engineering of food production

The process of genetic engineering foods is different from selective breeding because it allows scientists to select desirable traits and avoid undesirable traits that maybe occurs in the process of selective breeding [16]. Four main steps of genetic modification of food:

1. Identify

Firstly, scientists have to decide and select desirable traits such as resistance to drought, herbicides, insects or diseases. Then, they find an organism that already has that specific trait within its genes.

2. Copy

After scientists find the gene with the desired trait, they copy it with the process called " DNA replication".

3. Insert

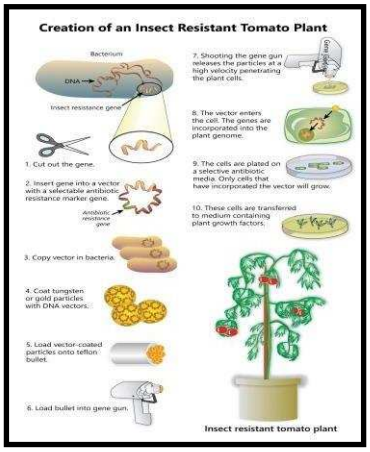
Next, scientists use tools to insert the desired gene into the DNA of an organism that they want. This new trait does not affect other existing traits.

4. Grow

Finally, scientists grow a new organism. If successful, scientists can increase the quantity of this organism quickly and widespread its use [16].

Advantages of genetic engineering in foods

- More nutritious food
- Prevention of disease and drought
- Reduce the use of chemical substances
- Increased supply of food with reduced cost and longer shelf life
- Rapidly growing plants and animals
- Food with more desirable traits, such as potatoes that produce less of a cancer-causing substance when fried
- Medicinal foods that could be used as vaccines or other medicines



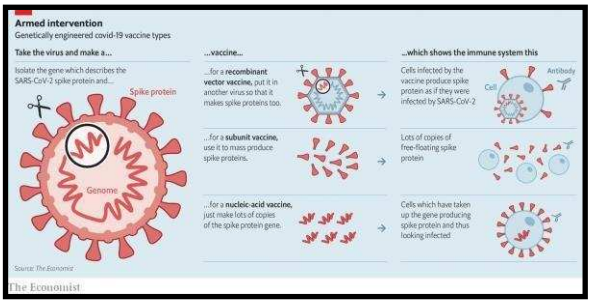
picture 10: the creation of an insect-resistant [17].

picture 11: examples of GMO products [17].

The development and production of covid-19 vaccines

The development of vaccines is a complicated and time-consuming process. Fundamentally, the process of developing vaccines is approximately 12-15 years. Indeed, vaccines are used to prevent the occurrence of diseases not to exhibit or treat diseases. Vaccines provide the immune system with the necessary instructions for recognising and memorizing lines of defence against diseases such as bacteria or viruses. However, the covid-19 pandemic immediately occurs and rapidly spreads in many countries. This causes many people to die from detrimental diseases that can infect through contact. Therefore, researchers have to accelerate the production of vaccines to prevent and stop this pandemic. Genetic engineering vaccine is suitable for this situation because it can provide numerous vaccine production in a short time [18]. Many researchers use data from the genome of the virus to make an outline to select appropriate antigens. The diagram is made of DNA or RNA that has hereditary guidelines. The cell's apparatus utilizes the guidelines to make virus antigens that the immune system responds to. Messenger RNA (mRNA) conveys guidelines for the assembly of protein from the DNA in the nucleus to the ribosome in the cytoplasm. This is help researchers to easily emphasize specific genetic sequences that encode proteins that are one of a kind to the attacking virus. In the COVID case, this is the natural spike protein that empowers the Covid-19 virus to enter human cells.mRNA is twice fast as your cells close to the infusion site to produce the spike protein. This point allows the immune system to fabricate antibodies and T-cells to defend against the covid-19 virus disease when it comes. Viral genomes can be cloned, and their genes are generated in whole or in part in microbial or animal cells in culture thanks to the wide range of technologies established for the synthesis and manipulation of recombinant DNA molecules. The immunological value of additional viral components is increasingly acknowledged, and the immediate applications for vaccine development have focused mostly on envelope proteins.

The production in microbial cells of genes from pathogens that produce surface antigens capable of producing neutralizing antibodies in the pathogen's host is the basic application of contemporary genetic manipulation tools to vaccine development [19].



picture 12: the process of vaccine production [19].

The risks of genetic engineering

The concept of risk is one of the most essential elements in consequentialist analyses of genetic engineering. There are many risks involved in genetic engineering. The release of genetically altered organisms in the environment can increase human suffering, decrease animal welfare, and lead to ecological disasters. Health risks related to genetic engineering food are concerned with toxins, allergens and genetic hazards. There are three main hazards of the mechanism of food. Firstly, they have inserted gene and their expression products. Secondly, the pleiotropic effects of gene expression. Finally, insertional mutagenesis results from gene integration. Considering these three hazards, new proteins can be synthesized that can produce unpredictable allergenic effects. Due attention should be taken to foods engineered with genes from foods that commonly cause allergies, such as milk, eggs, nuts, wheat, legumes, fish, molluscs and crustaceans. However, since the products of transgenic are usually identified, the amount and effects of the product can be assessed before public consumption [20]. Moreover, the disease is a major factor and one of the most effective tools that account for controlling the human population. Extending the lifespan of everyone by using genetic engineering in humans may result in outgrown numbers of humans. There is insufficient evidence to conclude that genetic-engineering organisms and genetic-engineering foods can increase cancer risk. In addition, there are many ethical concerns about genetic engineering and safety is the priority to consider. Researchers and ethicists who have written and spoken about genome editing agree that it should not be used for clinical reproductive purposes. The risk cannot be justified by the potential benefit. Moreover, the concern about justice and equality must be considered, it seems that genetic engineering can be only accessible to the wealthy and increases discrimination in healthcare. Lastly, researchers and bioethicists also worry about the possibility of obtaining truly informed consent from prospective parents as long as the risks of germline therapy are unknown [21].

The use of genetic engineering in the future

Genetic engineering has a long way to go before it can call itself revolutionary though. Aside from the scientific obstacles it encounters, it will have to overcome some more practical challenges, the first being persuading the public that it is a force for good, rather than conjuring images of evil corporations playing god. It needs to inform people in a much better way than it is doing right now, so people are informed and knowledgeable on the subject [22]. Education is the most essential way of convincing people about the project. With any modern technology, the environmental and ecological effects are the most important to consider and alleviate in our current age of environmental breakdown. The problem with genetic engineering is that private companies are carrying out a large proportion of the research and implementation, and corporations don't have the best track record for

looking after the planet [23]. To help figure out these ethical debates, genetic engineering needs to start referring to other fields of study, to become properly interdisciplinary. For example, philosophers should be asked to help consider potential problems that may occur, as they have been during the debate around AI [24]. Economists need to be included in the debate to reconcile the financial impacts genetic engineering entails. Historians should be consulted as they are the best source of information about the last time genetics were invoked to improve society around the turn of the twentieth century, meaning society can avoid making the same mistakes, so the general public is sufficiently informed to make the best information about something that could change the way they live forever [25]. Any decision to manipulate (or not manipulate) plants, animals, or landscapes is primarily ethical in nature, rather than scientific. So, as we cogitate on the potential development and release of genetically modified organisms (GMOs) for the purpose of advancing biodiversity, it is helpful for scientists and citizens to be conscious of what values we want to guide us.[26].

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