The Use Of DNA Polymerase Chain Reaction In Biotechnology

DNA polymerase is a type of enzyme that is responsible for forming new copies of DNA, in the form of nucleic acid molecules. Nucleic acids are polymers (large molecules made up of smaller, repeating units) that are chemically connected to one another. DNA is composed of repeating units called nucleotides or nucleotide bases (Nature Education, 2014). The polymerase is an essential enzyme for DNA replication, and usually work in pairs to create two identical DNA strands from a single original DNA molecule (ScienceDirect, 2019).

Thermus aquaticus was first discovered in Yellowstone National Park in 1969. It is single celled and an ancient bacterium, with optimum temperatures of approximately 70 degrees Celsius (Dr. Foldesi, B., 2018). Proteins inside bacteria usually become non-functional under extreme temperatures, changing their structure (Dr. Foldesi, B., 2018). However, Thermus aquaticus is able to survive as well as thrive under these conditions; making it an extremely useful bacteria in the aid of genetic technology (Barr, C., 2018).

In 1983, the polymerase chain reaction (PCR) was discovered by scientist Kary Mullis. This is the reaction that makes millions of copies of the DNA extracted from cells (Khan Academy, 2019). However, this method required the DNA to be heated up to high temperatures, destroying all proteins necessary to copy the DNA (Barr, C., 2018). High temperatures are necessary in the polymerase chain reaction method, as double-stranded template DNA must be heated in order to denature the strands, causing them to separate into two single strands (YourGenome, 2019). This step is vital in polymerase chain reaction. Without the separation of these strands, the DNA cannot be copied (Your Genome, 2019). Because Thermus aquaticus' proteins are heat-stable, one of its proteins, Taq DNA polymerase, could keep copying DNA, even after being heated up (Dr Foldesi, B., 2018). This allowed for the production of large quantities of DNA, providing a hugely beneficial resource in the study of genes and beginning the revolution of gene technology (Barr. C., 2018). The Polymerase Chain Reaction is a significantly effective tool used in biology, medicine, and forensic sciences to copy DNA for analysis.

The PCR consists of three steps run in a cycle; denaturation, hybridisation and polymerisation. In denaturation, the probe is heated to about 90 °C to split the double-stranded DNA into two single strands (Cicchetti, G., Köster, V., 2013). This is where the usefulness of the stability of Thermus aquaticus in extremely high temperatures is applied. In hybridisation, at about 60 °C, two very short pieces of DNA, called primers, bind to the single strands. In polymerisation, at about 70 °C, the Taq polymerase synthesises new double strands out of the single strands (Cicchetti, G., Köster, V., 2013). Once the DNA has been amplified through polymerase chain reaction, it can then be analysed to determine its origins (Harris, W., 2001). Short tandem repeat analysis (STR) is commonly used in DNA analysis. It examines how often base pairs repeat in specific locations on a DNA strand (Harris, W., 2001). These can be repetitions of two, three, four or five base pairs (Harris, W., 2001). Tetranucleotide (four base pairs) and pentanucleotide (five base pairs) repeats in samples that have been through PCR amplification are most commonly analysed, as these are most likely to be accurate (Harris, W., 2001). The likelihood that any two individuals (except identical twins) will have the same 13 locations in

their DNA profile is greater than 1 in 1 billion (Harris, W., 2001). Therefore, the use of PCR in DNA amplification is one of the most beneficial discoveries to biology, particularly molecular biology, the field of science, in terms of accurate DNA analysis.

The Use of Polymerase Chain Reaction in Biotechnology:

The PCR only requires a small amount of initial intact DNA; and can therefore be effective with only a single strand of intact DNA. This is often critical for forensic analysis where only trace amounts of DNA are available. PCR has also been used to amplify and analyse ancient DNA for anthropologic and archaeological purposes (LabCE, 2019). In criminal investigations, the amount of DNA available for analysis is limited to whatever can be isolated from a few strands of hair, skin cells, blood or other bodily fluids left behind at the scene. PCR represents a fast, cost-effective, and relatively easy tool that can rapidly amplify specific sequences from the isolated DNA, increasing the amount of material and paving the way for further analysis (BiteSize Bio, 2014). Without the discovery of taq polymerase in Thermus aquaticus, and therefore the introduction of PCR to forensic sciences, DNA evidence would be extremely difficult to amplify and therefore analyse, providing less significant evidence in relation to crimes and investigations.

Genetic and genome engineering is a useful tool for researchers, from producing proteins to understanding disease, and the polymerase chain reaction has a vital role supporting this process by cloning the DNA fragments used to modify the genomes of the bacteria, yeasts, animals and plants used in biological, agricultural and medical research (Coney, R., 2012). The cloned DNA fragments as a result of PCR can be inserted into the target organism; including microorganisms, plants or animals, using carriers such as bacteria and viruses. Some of these traits can be passed on to the next generation (Coney, R., 2012). Genetic modification is a technology that involves inserting DNA into the genome of an organism (The Royal Society, 2016). To produce a GM plant, new DNA is transferred into plant cells (The Royal Society, 2016). Usually, the cells are then grown in tissue culture where they develop into plants (The Royal Society, 2016). The seeds produced by these plants will inherit the new DNA (The Royal Society, 2016). This new DNA is provided by many processes, including polymerase chain reaction. Without the replication and amplification of the DNA that is necessary to transfer into the plant cells, there would not be enough for the plant to inherit. PCR can also be used to detect the presence and quantity of known genetically modified organisms (GMOs) in the environment, by detecting the sections of DNA that are known to be modified (Coney, R., 2012).

Scientists have only begun to unravel the secrets hidden within the human genome; the genetic blueprint for a human being. The mapping of the genome was finished in 2003, and scientists are continuing to discover what each gene does and how it functions (Layton, J., Bonsor, K., 2019). Designer babies are fast becoming a modern possibility for parents. It is now scientifically possible to manipulate the genes of embryos. Genetic engineering is now giving parents the opportunity to choose anything from their baby’s eye colour and hair colour to eliminating possible disease genetics. By amplifying selected DNA, and therefore genes, through the use of the polymerase chain reaction, it is now possible to inject this DNA into a fertilised egg, to give the foetus the properties of the parent’s desire.

Social and Ethical Issues of the Use of Polymerase Chain Reaction in Biotechnology:

The benefits of genetic engineering include more nutritious and tastier food, disease and drought-resistant plants, plants that require less fundamental resources (water, fertiliser, pesticides), an increased supply in food with longer shelf life and reduced cost, faster and larger growing plants and animals, and improved medicinal methods (MedicinePlus, 2019). The list of genetic engineering benefits is ever growing, with significant progression continuing to be made in the field.

Although the positive impacts of this field could be enormous, there are also social and ethical issues that are raised as a result of the progression of this field. New organisms created by genetic engineering could present an ecological problem. A genetically engineered species could have drastic impacts on the environment (Patra, S., 2015). The release of a new genetically engineered species would also have the possibility of causing an imbalance in the ecology of a region (Patra, S., 2015). The science has not been perfected yet, and accidents or misprints are high possibilities. An accident in engineering the genetics of a virus or bacteria could result in a stronger type, which could cause a serious epidemic when released (Patra, S., 2015). This could be fatal in human genetic engineering creating problems ranging from minor medical problems to death (Patra, S., 2015).

Due to the possibility of edits in the wrong place, and some cells carrying the new gene but others not carrying it, safety is of primary concern. Researchers and ethicists generally agree that until germline genome editing is deemed safe through research, it should not be used for clinical reproductive purposes; the risk cannot be justified by the potential benefit (Burnett, L., Barlow-Stewartand, K., 2007).

Future Uses or Implications of Polymerase Chain Reaction Use

In this new world of biology, if it can be imagined, it can eventually be created. Genetic engineering offers the chance to engineer cures far more effective than what nature could produce. Cures for terminal genetic disorders, deadly diseases and viruses are fast becoming a reality with the ever-growing revolution of gene technology (Walsh, B., Savulescu, J., 2018). By tweaking individual genomes or selecting specific embryos to avoid health problems, disorders, diseases and viruses can be defeated, or perhaps overcome altogether. New advances in genetic technology can also give rise to ‘superhumans,’ born as designer babies, who are optimised for certain characteristics (like intelligence or looks) (K.N.C., 2019). People will soon be able to make decisions about their lives in ways that were impossible in the past, but are fast becoming a possibility for the future (K.N.C. 2019). Growing understanding of gene technology is introducing incredible medical applications, like using genome sequencing and gene therapies (both of which DNA manipulation and amplification as a result of polymerase chain reaction) to fight cancer and other diseases (K.N.C., 2019). Cancer may soon become as simple to cure as the common cold, saving and improving millions of lives and decreasing more threats to human nature. While these are all credible solutions that will eventually work to address problems problems threatening human nature, such advances in technology eliminate processes of natural selection. At this rate, the age expectancy of humans will only continue to increase, having a significant impact on society and on the environment as the world tries to make way for more humans. While such diseases like cancer could be defeated, this doesn’t improve the quality of life for older people who would otherwise di;, and they would just continue to get weaker as the world continues to grow around them. Overpopulation is already a huge problem that the world faces, affecting the whole of society through costs, environmental

damage and poorer quality of life.

The healthcare applications of genetic technologies are only the start of where these technologies are taking the course of human nature to. The ability to select embryos during in vitro fertilisation (IVF), based on genetic predictions of both health-related traits and intimate characteristics like height, IQ and personality style, will continue to increase over the coming years as society becomes more accepting of these changes. Stem cell technologies can be used to expand the number of eggs that potential mothers can use in IVF, and therefore the range of reproductive options for parents, ultimately eliminating infertility (K.N.C., 2019). However, while this displays as an extreme benefit of gene technology for such a widespread issue as infertility, it also lends a hand in contributing to overpopulation, which cannot be solved by gene technology and is fast becoming one of human nature's biggest threats.

Specific areas of biotechnology show promise for likely application in 2025 such as personalised medicine, genome engineering, human gene therapy, biomanufacturing, biofuels, environmental remediation, genetic engineering of disease and drought-resistant plants, synthetic biology, nanotechnology, biotechnology and engineering (Perkins, E., Steevens, A., 2019). Significant research is currently being conducted on the introduction of personalised medicine to society (Perkins, E., Steevens, A., 2019). Personalised medicine is the customisation of healthcare tailored to an individual patient based on their genetic content, or other molecular analysis such as drug metabolism (Perkins, E., Steevens, A., 2019). These factors help to select medical treatments to suit an individual's needs. The goal is to develop tests that will predict which patient genetic profiles are mostly likely to benefit from a given medicine (Biotechnology, 2019). Genetic data is already routinely collected so that researchers can determine whether different responses to a test medicine might be explained by genetic factors (Biotechnology, 2019). By introducing personalised medicine to society, such current issues as antimicrobial resistance may be eliminated, as the drugs that people are prescribed will be designed to suit their specific needs based on their genetic profiles (Biotechnology, 2019).