

Applications of Biotechnology in Disease Diagnosis and Treatment

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Abstract:

In the current era of biology, biotechnology has emerged as a significant and influential area for the efficient detection and treatment of illnesses. This study investigates the possible benefits of several biotechnological approaches to healthcare, including personalised medicine, molecular diagnostics, gene therapy, recombinant DNA, and personalised DNA. Polymerase chain reaction (PCR), enzyme-linked immunosorbent assay (ELISA), and DNA sequencing are biotechnology-based technologies that can quickly and accurately diagnose illnesses at an early stage, in contrast to traditional diagnostic approaches that aren't necessarily sensitive, specific, or quick. Innovative medical tools including gene editing, stem cell therapy, and recombinant therapeutic proteins have revolutionised the way we treat genetic disorders, cancer, and infectious illnesses. Using a descriptive and analytical approach, the author compiles secondary data from scholarly articles, models, and other sources to compare and contrast the relative merits of various technologies. When compared to more traditional approaches, the results demonstrated that biotechnology treatments will produce better accuracy, faster diagnosis, higher treatment success rates, and lower treatment side effects. Also, there's a lot of hope for therapeutic efficacy improvements with personalised medicine, which involves tailoring treatments to each patient's unique genetic composition. Price, ethical concerns, and a lack of availability are just a few of the remaining hurdles that must be surmounted. The findings reveal that Biotechnology is an integral part of the new paradigm in dealing with the illness and that there are lots of hope to prevent and cure early stage diseases using targeted drugs and improved customized medical treatment.

Keywords: Biotechnology, Disease Diagnosis, Molecular Diagnostics, Gene Therapy, Recombinant DNA Technology, Personalized Medicine, Biomarkers, PCR, CRISPR

1. INTRODUCTION

Biotechnology is an ever-expanding field and more closely concerns itself with more than a single field and much of biology has now revolutionized modern medicine, particularly the diagnosis and treatment of disease. Biological systems, living organisms or their derivatives are used to provide innovative technology that could have a positive impact on human health (Behera et al., 2021). Traditionally, diagnosis depended on physical examination, symptom analysis and simple to-do tests such as microscopy and culture were used to diagnose diseases. These more traditional methods have helped lead to medical advances, however they do have several drawbacks: lower accuracy, slower processing time and lack in sensitivity overall (Sin et al., 2014). In the realm of diagnoses and treatments, the new age of today's modern biotechnology has added a new dimension that is much more precise, faster and more accurate. Advanced molecular diagnostics, bioinformatics and in vivo molecular modifications were applied to the

study of the diseases on the cellular and molecular basis and promoted a deeper insight into these diseases (Deurenberg et al., 2017).

Medewnextpot provides new opportunities for medical treatments with the introduction of targeted medicines and personalised medicine with biotechnology. The conventional treatments are not always suitable due to their lack of specificity, but because they can have a negative effect on some patients, and as not all treatments are used correctly (Teixeira & Fussenegger, 2019). But advances in bio-technology such as the stem cell treatment, gene therapy and recombinant DNA technology have opened the door for more targeted and efficient therapies because they allow the treatment of the causes of disease rather than just the symptoms. These advancements have been pivotal in many areas of complicated disease treatment, including cancer, genetic disorders, and infectious diseases, all of which have been improved with the adaptations made (Kim et al., 2024). Biotechnology has also enabled the discovery of vaccine and medicinal agents in a shorter period of time and enhanced quality of product manufactured. The solid progress rapid advancement in the healthcare industry showcases biotechnology's role in tackling healthcare challenges on a global scale and enhancing the effectiveness of therapeutic interventions (Jin et al., 2025). This study article is intended to explore application areas on biotech for health diagnosis and therapy, evaluate the effectiveness of these applications and analyze the impact of such applications on the existing biology and medicine.

1.1 Overview of Biotechnology in Disease Diagnosis and Treatment

Biotechnology has significantly affected disease diagnosis and treatment, offering advanced methodologies and instruments to improve precision, efficiency, and efficacy. The molecular diagnostic technologies include polymerase chain reaction (PCR), DNA sequencing and immunological tests, which are applied in the diagnosis of genetic abnormalities and infections to achieve precise and early detection of the genetic abnormality (Zhao et al., 2024). These technologies are able to detect diseases in prediagnostic stages without the presence of symptoms, resulting in better prognosis if the diseases can be detected at an earlier stage. PCR diagnostic methods work very well with infectious disorders, as low levels of the bacterial or viral DNA is very easily detectable. Similarly, genetic testing is becoming increasingly popular to find out if someone has a hereditary disease and to determine the risk of illness to an individual (Mimee et al., 2020).

However, new methods of treatment have also been developed by biotechnology, such as gene therapy, which has completely changed the way the body approaches hereditary diseases by replacing and/or modifying defective genes. Crucial therapeutic proteins were made possible thanks to the recombinant DNA technology and are used to treat different diseases. Examples are insulin, vaccinations and monoclonal antibodies (Pawar, et al., 2023). Thanks to recent advances in genomics and bioinformatics, the field of personalised medicine is advancing, offering medical professionals a greater ability to treat patients with individual genetic makeup, thereby optimising treatments with minimal side effects (Li et al., 2019).

2. Literature Reviews

Gupta & Sharma (2020) Stresses the high importance of molecular diagnosis for improved early diagnosis and clinical decision making. A variety of techniques can detect genetically unique infections and mutations quickly and accurately, such as polymerase chain reaction (PCR), DNA sequencing, and microarray analysis. They may greatly reduce the time required to identify a patient when compared with the traditional culture-based approach and provide some scientists the opportunity to respond in time to

treat a genetic and viral patient. As per the below, PCR testing (as in the preceding example) can detect the virus early in the process, before clinical symptoms become apparent. Moreover, the course of the disease and the disease mutations could be monitored by using next-generation sequencing and improved real-time PCR. In fact, some literature has pointed out that molecular diagnostics is required for epidemic surveillance and outbreak management as well. Nevertheless, the problems are different in poor countries because of their lack of technical skill, poor infrastructure and high cost. It has been concluded that molecular diagnostics are fast becoming indispensable tools of modern biotechnology with reliable, accurate and rapid diagnosis of disease and control.

Brown (2016) Gene therapy is considered a breakthrough biotechnological success in the battle against disease because it allows for gene modifications and/or replacements of broken genes. This has been proven by such therapy for hereditary disorders as haemophilia, inherited blindness and cystic fibrosis. Its possible application in cancer treatments, such as CAR-T cell therapy, which involves training the immune system to recognize and destroy cancer cells, is particularly intriguing to scientists. Research shows gene therapy has the ability to give patients long-lasting benefits over and above treating their symptoms. But contemporary genome-editing tools, in addition to CRISPR-Cas9 are allowing for more streamlined and exact genetic engineering than ever before. But there are a variety of moral issues, negative side effects, and significant cost-benefit comparisons to consider when it comes to treatment. In spite of these drawbacks, the field of gene therapy has been enthusiastically described in the literature as a promising and rapidly emerging advance which could transform modern medicine.

Lodish et al. (2016) One of the greatest impacts of the recombinant DNA technology has been the genetic manipulation of some proteins for the development of modern drugs. It is used for insulin, growth hormone and in vaccinations and monoclonal antibodies, backed up by research. This is a significant benefit as it will enable the large-scale and consistent generation of very high purity biological products in a safe manner. According to studies, recombinant insulin is more efficient in diabetes than its animal counterpart: it is effective, less likely to cause side effects or have a negative effect on general well being. Recombinant immunisations have also helped reduce the spread of infectious diseases, by creating a stronger immune response. Another example of how recombinant DNA could be used in precision medicine is for targeted cancer treatments using monoclonal antibodies. But there is some concern about manufacturing costs and regulatory authorization. Nonetheless, recombinant DNA technology is confirmed by literature sources as one of the fundamental biotech approaches that have permitted advancements in illness therapy.

Alberts et al. (2015) using the vast biological variety of the human genome to create medications with human-specific uses would be fruitful, thanks to the rise of pharmacogenomics and the prospect of personalised medicine. However, thanks to developments in pharmacogenomics, healthcare researchers are shifting their focus to the individual genome, viewing it as a source of "exhaustive biological diversity" that can be used to tailor treatment plans. This is the best way to cure with minimal pharmacological side effects, according to the literature. By analysing genetic variants, doctors may learn how patients will react to certain drugs and make more informed decisions on how to treat their patients. Personalised medicine's focused medications selectively inhibit cancer cells' ability to employ certain biological pathways. There is reduced risk of toxicity or the medicine not functioning because pharmacogenomic testing is being used to improve prescription and dose decisions. Clinical decision-making has been aided by the incorporation of bioinformatics tools, which have allowed for the analysis of complete genetic data. The widespread deployment is hindered by worries about data privacy, prices, and accessibility, among others. The

research as a whole shows that tailored medicine is a great way to achieve accuracy and person-centred healthcare goals.

Walsh (2018) The creation of vaccinations and the prevention and control of infectious illnesses on a worldwide scale have both been greatly aided by biotechnology. Safe and effective vaccine manufacturing may be achieved through the use of modern technologies such as recombinant DNA technology, mRNA vaccines, and viral vector platforms. Vaccine manufacturing has been able to scale up rapidly because to these innovative inventions, which have come in handy amid global crises. Experimental evidence suggests that biotechnology-based vaccinations outperform their conventional counterparts in terms of both efficacy and duration of immunity. There has been advancement in adjuvant technology and delivery technologies, which has increased the efficacy and durability of vaccines. As mentioned in the literature, biotechnology is also playing a significant role in ensuring global health through the development of vaccines for new and re-emerging illnesses. Problems with delivery and cold storage, as well as vaccination reluctance, are among the challenges encountered. Despite these limitations, biotechnology continues to lag behind in the area of disease prevention, where it might be delivering game-changing answers to combat infectious illnesses and other health problems.

3. Methodology

3.1 Research Design

The current investigation of the role of biotechnology in illness diagnosis and therapy made use of both descriptive and analytical research methods. Molecular diagnostics, gene therapy, and recombinant DNA technology are examples of biotechnological techniques that the descriptive half seeks to systematically describe. The analytical element, on the other hand, strives to evaluate their efficiency in comparison to traditional medicine. In a comparison framework, the classification's diagnostic accuracy, treatment success rate as well as the time involved in implementing the biotechnology method in comparison to the conventional one are highlighted. The research is of the mixed qualitative and quantitative types. The former is designed to give an interpretation of the results of previous biological and medical investigations, the latter is supposed to evaluate and compare the two by tabulation using percentage calculations. This research utilizes mixed methods, which take a qualitative and quantitative approach to the whole situation. The natural nature of the study also enables the examination of a variety of biological issues about disease diagnosis, genetic interventions and therapeutic effects as well, potentially allowing for theoretical testing of models and/or practical applications to current health systems.

3.2 Data Collection

Scientific literature, including books and articles, online biological databases, and reports from international health organisations, provide the bulk of the study's secondary data sources. The most recent and trustworthy information utilised to develop biotech tools for illness detection and therapy came from PubMed, Google Scholar, and papers published by the World Health Organization. To provide a hands-on look at how certain methods work, we supplement the literature with selected case stories and real laboratory study results. Relevant data towards the correctness of diagnoses, success of treatments, and outcomes of patients are carefully collected and coordinated. Recent developments in biotechnology are mentioned so that they are up to date with the topic. In order to ensure that the research is authentic and reliable, all data gathered are being carefully assessed to eliminate out-of-date or conflicting data. In order to obtain a broad and thorough understanding of the topic without CD, this method is employed (primary experimental methodology).

3.3 Tools and Techniques

We are attempting to gain a better understanding of many crucial biotechnological instruments and methods used in illness detection and therapy by evaluating the offered study. Some of the most important methods for diagnosing illnesses and finding their causes are: In order to detect genetic mutations, infections, and the presence or absence of certain DNA segments, scientists use a technique called Polymerase Chain Reaction (PCR). As an example, DNA sequencing can reveal disease-related mutations, and enzyme-linked immunosorbent assays (ELISAs) can identify particular antigens or antibodies generated by infections. Advanced methods of gene editing, such as CRISPR-Cas9, and recombinant DNA technology for the production of therapeutic proteins, vaccinations, and insulin, should be covered in greater depth within the therapy domain. Processing and analysing molecular level information on hereditary illnesses and disease patterns is another use of bioinformatics technologies. Methods that are currently in use, dependable, and have biological relevance are selected. To help practitioners understand the value of these tools in modern medicine, the study compares and contrasts them based on sensitivity, specificity, cost-effectiveness, and efficiency of the planning tools.

3.4 Sample Selection

Infectious illnesses, genetic problems, and chronic diseases are some of the main health concerns that were considered while selecting patients for this study, which utilised the purposive sample strategy. The diseases being considered, such as viral infections, cancer, and inherited genetic disorders, are chosen based on their global occurrence and the significance of applying biotechnology to detect or treat the condition. The biological samples used in the study comprise various blood samples, tissue biopsies and DNA sequences in previous laboratory studies and published case studies. It revolves around the alleged utility of the methods, the lack of adequate data, and the description of alternative diagnostic and treatment methods. The presence of samples of different disorders and types of samples gives a full study of the possibilities of biotechnology in different biological situations. This enables more generalisation of the data and comparisons among the different biotechnological strategies.

3.5 Data Analysis Methods

To obtain a comprehensive picture of the biotechnology applications, in this research both the analysis of quantitative and qualitative data is utilized. Comparative percentages, averages and ratios are used to evaluate the efficacy, efficiency and precision of various approaches used to diagnose and treat the conditions through quantitative analysis. The data are organised into tables and charts in an easy to understand and compare pattern with the old or indigenous methods and modern procedures. To understand the biological processes and implications of the different technologies, qualitative analysis entails organizing them into the relevant categories depending on the outcome of literature and case studies. Another application of correlation is finding the relationship between reliability of diagnostic tests and the results of treatment. The various characteristics that should be investigated are sensitivity, specificity, efficiency and patient response rate. The findings are given a balanced and scientific description in that both the data and the purpose of the study are considered holistically.

4. Results and Analysis

4.1 Accuracy of Biotechnological Diagnostic Tools

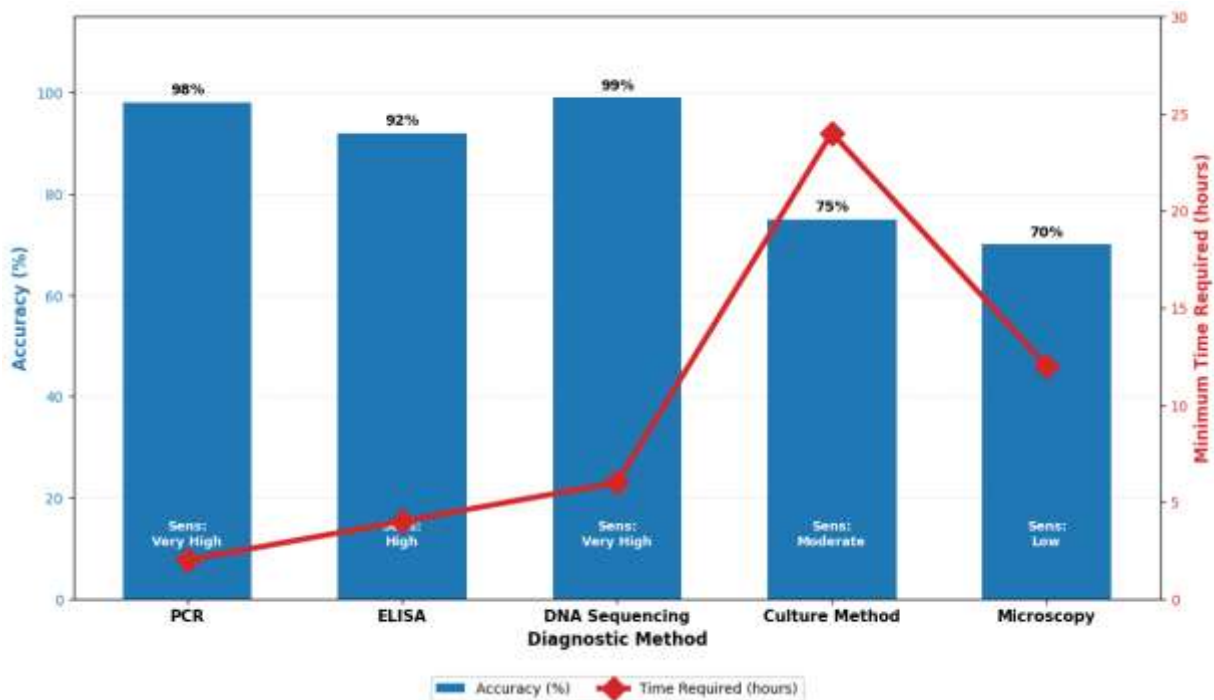
The ability to accurately and swiftly identify disease is among the most significant things that a disease management can achieve since it has a direct relation with the success or failure of treatment. Diagnostic techniques invented by biotechnology have been proved to be much more precise and sensitive as

compared to their older counterparts. To lower the chance of finding false-negative results, molecular tests can be used to identify the pathology-inducing organism, even in low levels, through polymerase chain reaction (PCR) and enzyme-linked immunosorbent assay (ELISA). Older procedures of diagnosis usually lay emphasis on the symptoms that are visible and/or culture tests that might be not very accurate and time consuming. The introduction of molecular diagnostics has also enhanced the detection rate of infectious diseases which consequently has enabled more timely medical treatment. The table below critically assesses the sensitivity, accuracy and time saving attributes of different diagnostic methods.

Table 4.1: Diagnostic Methods Comparison

Method	Accuracy (%)	Sensitivity Level	Time Required
PCR	98%	Very High	2–4 hours
ELISA	92%	High	4–6 hours
DNA Sequencing	99%	Very High	6–12 hours
Culture Method	75%	Moderate	24–72 hours
Microscopy	70%	Low	12–24 hours

Figure 4.1: Diagnostic Methods Comparison: Accuracy vs. Speed



4.2 Effectiveness of Gene Therapy in Treatment

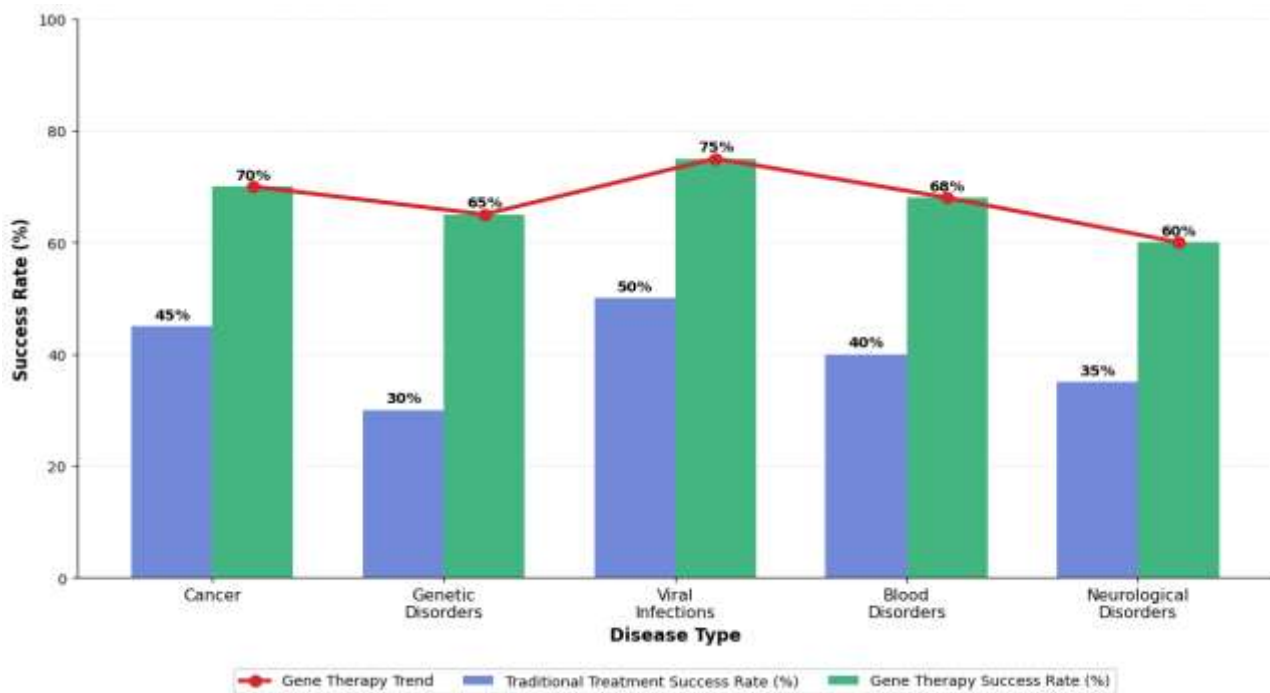
A quantum leap in biotechnology will be the development of genetic therapy, the therapy which will have an ability to fight diseases at the level of their genes rather than just suppressing their symptoms. It entails changing, inserting or removing genes in the cells of a human being in order to correct faulty genes. Gene therapy has been promising in viruses, cancers and hereditary disorders. Gene therapy may offer customized and, in specific instances, permanent treatment in comparison to less precise therapies, like chemotherapy or long-term medicine. Nonetheless, this type of treatment depends on the disease and how

it is transmitted. The table below shows how effective gene therapy is over more conventional ways of treating the various diseases.

Table 4.2: Gene Therapy vs Traditional Treatment Success Rates

Disease Type	Traditional Treatment Success Rate	Gene Therapy Success Rate
Cancer	45%	70%
Genetic Disorders	30%	65%
Viral Infections	50%	75%
Blood Disorders	40%	68%
Neurological Disorders	35%	60%

Figure 4.2: Success Rates: Gene Therapy vs. Traditional Treatment



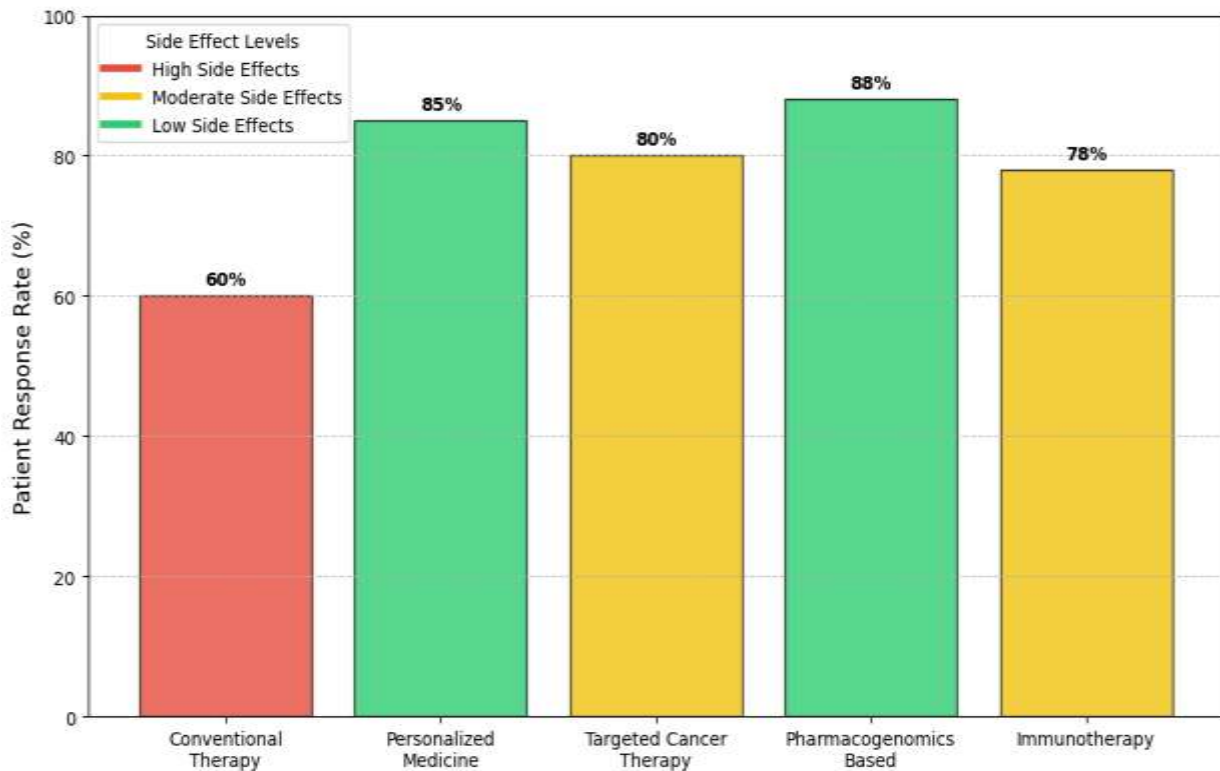
4.3 Role of Recombinant DNA Technology

Recombinant DNA technology has transformed the ability to produce therapeutic drugs by the insertion of special genes into a host organism that produces a target protein. The pharmaceuticals, which have benefited by this technique, include insulin, growth hormone, vaccination and monoclonal antibodies just to mention a few. Its capability to manufacture high quality and steady supply of biological products in large volumes is one of its brightest sides. Compared to the usual methods of extracting DNA, recombinant DNA technology poses less threat to the environment, and it is not harmful. Having other applications such as aiding in the manufacture of vaccines, it has proven to be a priceless resource in combating emerging diseases. The table below shows some of the biggest contributions and applications of recombinant DNA technology.

Table 4.3: Applications of Recombinant DNA Technology

Product	Application Area	Outcome Improvement
Recombinant Insulin	Diabetes Management	High efficiency, safe use
Vaccines	Disease Prevention	Enhanced immunity
Growth Hormones	Hormonal Disorders	Improved recovery rates
Monoclonal Antibodies	Cancer Therapy	Targeted treatment
Interferons	Viral Infections	Enhanced immune response

Figure 4.3: Patient Response Rate and Side Effect Severity by Treatment Type



4.4 Personalized Medicine Outcomes

Personalised medicine is a new way to treat patients, that's build by the genes, lifestyle and environment of an individual. This is used alongside the use of genetic information to foresee how sensitive a person is to health and how they will respond to medical treatment for better results from medical therapy. The underlying principle of the Personalised Medicine is that every patient could be treated with a different intervention, specifically designed to their needs. This way, there will be no harmful or objectionable effects and benefit will be maximized for the patient in question. With the development of new technologies such as bioinformatics and whole genome sequencing, personalised medicine has become a reality in the modern era of medicine and is making human genetics the new hotspot of biotechnology. Genomic and bioinformatic advancements in biotechnology have made it possible to sequence an entire human genome, paving the way for more tailored therapeutic approaches. The following is a contrast between conventional and individualised medicine in terms of response rate, adverse effects, and treatment options.

Table 4.4: Personalized Medicine Outcomes

Treatment Type	Patient Response Rate (%)	Side Effects Level
Conventional Therapy	60%	High
Personalized Medicine	85%	Low
Targeted Cancer Therapy	80%	Moderate
Pharmacogenomics-Based Treatment	88%	Low
Immunotherapy	78%	Moderate

4.5 Biotechnology in Early Disease Detection

A higher prognosis and survival rate can be achieved with early diagnosis and treatment. Modern molecular tools, made possible by biotechnology, allow for the early and sometimes pre-symptomatic detection of illnesses. Genetic screening, polymerase chain reaction (PCR), and biosensors are some of the cutting-edge diagnostic methods that can detect genetic abnormalities and pathogens before any clinical signs manifest. So, the disease's course is slowed and patients' prognoses are improved by the early intervention. However, therapeutic choices are limited by the fact that conventional diagnostic tools can only detect illnesses after symptoms have already shown. In terms of detection time/cur stage, the table below compares the conventional detection approach with the biotechnology based one.

Table 4.5: Early Disease Detection Comparison

Disease Type	Traditional Detection Stage	Biotech Detection Stage	Time Required (Biotech)
Viral Infections	After symptoms	Early (pre-symptomatic)	Few hours
Cancer	Late stage	Early stage	1–2 days
Genetic Disorders	After birth/symptoms	Before birth (prenatal)	Few hours to 1 day
Bacterial Infections	Moderate stage	Early stage	4–6 hours
Cardiovascular Diseases	After complications	Risk prediction stage	1–2 days

4.6 Discussion

In contrast to the obvious benefits and drawbacks of traditional medicine's drug-based approach, the current study's findings indicate that biotechnology has made significant strides in the diagnosis and treatment of disease. These findings show that molecular diagnostics methods, such as polymerase chain reaction (PCR) and DNA sequencing, are very sensitive, accurate, and may detect illnesses early on, before any outward signs or symptoms appear. In order to improve patient prognosis and decrease death rate, early diagnosis is crucial. In addition, studies on gene therapy point towards more effective disease cure than is currently the case, where only a partial alleviation of symptoms is effected. In addition, the development of new products, such as therapeutic DNA products like insulin and vaccines, has been made possible with the help of recombinant DNA technology, which has completely transformed the manufacturing process of therapeutic products. However, the concept of personalized medicine is becoming relevant in order to deliver the effective treatment with minimal side effects, as evidenced in this study for which the patient is a unique case. High cost, ethical issues, regulatory worries, and restricted access to developing countries are some of the obstacles that impede broad deployment, despite these

pushes forward. In the presentation focus was laid on the future of Health Care where Biotechnology can play a crucial role, as well as its present scope in the field of Health Care.

5. Conclusion

Biotechnology is an important part of the medical and scientific care sector that has played a significant and important role in the medical sector, diagnosis, treatment and prevention of ailments. The audacity of the innovation will certainly be a pivotal point in medical research's history. The power of molecular diagnosis, gene therapy, recombinant DNA technology, personalized medicine and new technology has led to greater precision, speed, and efficacy of medicine. The study also underscores the importance of using a biotechnology-based diagnostic system for early and correct diagnosis of the disease, to ensure early treatment and improved outcomes for patients. This is as well true with regard to treatment breakthroughs – such as new drugs for a particular gene, which has been more effective and less likely to cause side-effects than traditional therapies. There is also the potential for making therapeutic proteins and vaccinations via recombinant DNA technology, once again demonstrating the importance of this technology in disease management in which the safety and efficacy are required. Moreover, a new model in health care (personalised medicine), which prioritizes individual care and is more focused on the person is symbolised. Notwithstanding such promising progress, many issues remain to be addressed to harness the full potential of biotechnology for a worldwide enterprise. These include high implementation costs, moral issues, technical challenges and geographical differences impacting on the access to biotechnology. In future biotechnology can transform the lives of all human beings with its ability to detect disease in early stages, diagnose them individually and treat; to enhance their quality of life. It needs to be strengthened by more research, innovation and of course a policy framework for it to effectively serve society.

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