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THE IMPACT OF INNOVATIVE BIOTECHNOLOGY ON PERSONALIZED MEDICINE IN THE PHARMACEUTICAL INDUSTRY

KATELL BARC

Work project carried out under the supervision of:

João Castro

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Abstract

This study explores the impact of innovative biotechnology on the advancement of personalized medicine and the pivotal role of biopharmaceuticals in enabling its development. Using a descriptive cross-sectional design and mixed-methods approach, data was collected from 108 participants globally to assess perceptions of PM's development, challenges, and future trajectory. Key findings highlight the significant contributions of biotechnologies such as Next-Generation Sequencing, CRISPR, and CAR-T therapies, particularly in oncology. Barriers like high R&D costs and strategies for fostering collaboration and public funding were identified as crucial for PM's adoption. The study underscores PM's transformative potential to revolutionize healthcare systems worldwide

Keywords: Personalized Medicine, Biotechnology, Pharmaceutical, Healthcare, Innovation

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1. INTRODUCTION

In the fast-changing realms of biotechnology and pharmaceuticals, a groundbreaking healthcare model is taking shape and receiving growing acknowledgment referred to as personalized medicine (PM). The National Center for Biotechnology Information (NCBI) defines biotechnology as a multidisciplinary field that utilizes living organisms to modify or enhance human health through technological applications (Gupta et al. 2016). Biotechnology has revolutionized diagnosis and treatment, particularly with the development of PM, which is often referred to as the "technology of hope".

PM emerged in the 1990s, driven by advancements in DNA sequencing and the Human Genome Project ("The Human Genome Project," n.d.). As PM evolves, it paves the way for innovation, transforming how diseases are understood, treated, and even prevented by tailoring medical treatments to fit the unique characteristics of patients (Goetz and Schork 2018a). The existing literature on PM tends to be highly medical-oriented and complex, often making it difficult for non-experts to understand. Additionally, most studies focus narrowly on a single viewpoint—either biotechnology, PM, or the PI—but rarely integrate all three into a cohesive framework. This study offers a unique and comprehensive perspective, bridging these fields.

Furthermore, while existing research strongly focuses on technical advances and clinical applications, there is a notable lack of studies assessing public perceptions of PM, especially among individuals with varying levels of familiarity. This study offers a wider and more accessible analysis, emphasizing the importance of innovation in PM and its capacity to revolutionize healthcare. It examines key trends, obstacles to adoption, and strategies based on informed public perceptions of the subject.

First, the literature review examines the evolution of PM and advances in biotechnology. Then, the methodology describes the research design, the results present the main conclusions,

and the discussion contextualizes these ideas. Finally, the study concludes with practical implications for the PI and suggestions for future research.

2. LITERATURE REVIEW

The literature review provides an in-depth understanding of the topic. It explores biotechnology's evolution and its role in PM advancement, highlighting economic implications, challenges, and integration into healthcare systems.

2.1. Biotechnology and its Evolution

2.1.1. The Role of COVID-19 in Shaping Modern Biotechnology's Growth

Modern biotechnology is at the forefront of innovation and progress in the rapidly evolving healthcare technology sector. It involves manipulating the products of the organism, such as cells, molecules, tissues, and organs, to develop innovative solutions for diagnosing, treating, and preventing disease while improving human health and well-being (Kholboy et al. 2024) According to Borzova (2024), the COVID-19 pandemic marked a significant turning point for the biotechnology industry, triggering a global boom in the sector at a time when many other markets were suffering from severe negative impacts. The author states that this rise can be attributed to "leapfrogging," where companies outperform the competition by bypassing an entire generation of technological development by adopting emerging or latest technologies. The pandemic created an urgent demand for innovative solutions and superior business models, compelling biopharmaceutical companies to develop solutions in record times (Borzova 2024). A notable example of this dynamic is the quick development of mRNA vaccines (such as Pfizer) in response to COVID-19. The global biotechnology market was estimated at US$852.88 billion in 2020 (Biospace 2022), and it has since grown to an estimated US$1.38 trillion, highlighting substantial economic expansion. Furthermore, it is projected to grow at a

compound annual growth rate (CAGR) of 11,8% from 2024 to 2033, showcasing the increasing importance of innovative biotechnology in the healthcare industry (GlobeNewswire 2024).

2.1.2. Historical Milestones in Biotechnology

The development of biotechnological innovations, such as vaccines, gene therapies, and biomarkers, revolutionized healthcare and has offered a wide range of novel and innovative solutions to long-standing problems that improve patient outcomes (Kaylor 2023). According to an article by the National Library of Medicine (Verma et al. 2011), although biotechnology is often considered a modern breakthrough, it has always accompanied humankind (Appendix 1). Ancient biotechnology dates back to before 1800 but did not consider any scientific understanding and was applied by observing natural processes. Classical Biotechnology spanned from 1800 to the mid-20th century and was marked by significant advancements. The work of Louis Pasteur and Robert Koch transformed medicine through the development and commercialization of vaccines, as well as sterilization techniques. Although these practices may seem banal to us today, they represented groundbreaking changes at the time, notably with the theory of germs as a foundational concept in understanding disease, and played a significant role in shaping modern biotechnology (Verma et al. 2011).

2.1.3. Revolutionary tool in Biotechnology: The Case of CRISPR-cas9

Today, in Modern biotechnology, "researchers aim to use biotechnologies to discover the underlying molecular causes of disease and intervene precisely at this level" (Rogers 2024). One key example of biotech innovation is CRISPR-cas9. This gene-editing tool enabled the deletion, repair, or replacement of the gene segment, offering a way to correct mutations or disabled genes involved in diseases (Zheng et al. 2018) (Appendix 2). It was developed by two researchers, Emmanuelle Charpentier and Jennifer Doudna, in 2012 and awarded the Nobel Prize in Chemistry in 2020 (Westermann, Neubauer, and Köttgen 2020). "CRISPR" stands for Clustered Regularly Interspaced Short Palindromic Repeats and refers to the specific

organization of short, repeated DNA sequences present in the genome of prokaryotes and "cas-9" stances for the protein that acts as a molecular "scissor" that binds to the desired DNA, enabling genetic modifications precisely at the molecular root (Asmamaw and Zawdie 2021). The first CRISPR-based medicine, commercialized under "Casgevy", was finally approved in 2023, transitioning from experimental trials to real-world applications (Henderson 2024). As seen in Appendix 3, CRISPR has been successfully applied to treat certain blood disorders, notably sickle cell disease (SCD), the most common genetic disease affecting 8 million people worldwide, causing severe problems such as pain crises, strokes, and lung problems (National Institute of Health 2024) As of August 2024, 29 out of 31 patients who used Casgevy did not experience pain crises or complications for at least a year after the treatment, highlighting the unprecedented accuracy of gene editing (Healey 2024). Moreover, CRISPR-cas9 is currently being tested in clinical trials to treat certain cancers, with promising initial results. If these advances are confirmed, this technology could revolutionize medicine by offering targeted, personalized treatments, thus transforming the fight against cancer (Appendix 4).

2.3. Evolution of Personalized medicine

2.3.1. From 'one size fits all' to personalized healthcare

Hippocrates (born approximately in 460 BC) is regarded as the "father of medicine" and is known for emphasizing on a patient-centered approach in healthcare and advocating for the idea of "treating the patient, not the disease" (Prasanthi Nori and Kiran 2021). He believed that disease resulted from a combination of environmental factors, such as dietary habits and lifestyle choices (Prasanthi Nori and Kiran 2021). Consequently, he argued that effective treatment should, therefore, be treated accordingly. The evolution of PM is deeply rooted in the need to tailor treatments to each patient uniquely, considering their genetic, environmental, and biological characteristics. The core of this approach is summed up in the four P's of PM, which

are predictive, making it possible to predict the risk of disease based on genetic information; personalized, focusing on treating plans tailored to each individual; preventive, aiming to prevent disease before it occurs; and participatory, encouraging active collaboration between patients and healthcare professionals in the decision-making process (Appendix 5) (Alonso, de la Torre Díez, and Zapiraín 2019). In contrast, traditional medicine focuses on symptoms to diagnose diseases and prescribe the general appropriate medication to cure the patient (Hewings-Martin 2017). However, as illustrated in Appendix 6, when it comes to medicine, one size does not fit all. With this recognition, the Precision Medicine Initiative (PMI) was launched by Barack Obama in 2015, aiming to "enable a new era of medicine through research, technology, and policies that empower patients, researchers, and providers to work together toward the development of individualized care"(Whitehouse.gov 2014). PM emerged in the 1990s, driven by advances in DNA sequencing technologies. These developments were made possible through the Human Genome Project, which decoded over 3 billion base pairs of the human genome with the global collaboration of researchers until 2003 (Appendix 7) (Visvikis-Siest et al. 2020). In conclusion, the evolution of PM is marked by the principle of "providing the right treatment at the right time to the right patient" (R.Mills 2017) (Appendix 8).

2.3.2. Intersection Between Biotech and Personalised Medicine

Innovations in Biotechnology are foundational to the advancement of PM. Both fields aim to tailor treatments to individuals by leveraging their unique biological characteristics, "utilizing microscopic elements of life to solve macroscopic problems related to human health"(Patsnap, n.d.). The tools and techniques provided by biotechnology can be separated into four categories: Genome-guided medicine, Therapeutics, Devices, and Diagnosis (Appendix 9). These advancements have not only enabled the feasibility of PM but also significantly transformed our approach to disease treatment (Appendix10) (Prasanthi Nori and Kiran 2021). A prime example of innovative biotechnology applied in personalized medicine

is Next-Generation Sequencing (NGS), which has been commercially available since 2006 (Morganti et al. 2019) and allows for the rapid and accurate analysis of millions of DNA or RNA molecules (Appendix 11). This technology is largely used in oncology, where approximately 75% of traditional drugs are ineffective for patients. This is followed by Alzheimer's disease, with a 70% ineffectiveness rate, and Arthritis at 50% (Mikulic 2024b)(Appendix 12). By identifying genetic mutations, NGS facilitates the development of targeted therapies cost-effectively and with unprecedented accuracy, grandly revolutionizing PM (Satam et al. 2023). Integrating biotechnology with PM promises to transform the healthcare industry, leading to the development of more precise, tailored, efficient, and safer therapeutic solutions for diverse medical conditions.

2.3.3. The Promises of Personalized Medicine

PM is evolving alongside advancements in data and calls for important changes in healthcare (Nardini et al. 2021). By leveraging biotechnological innovations, PM aims to address previously untreatable or irreversible conditions. It aspires to redefine human health by "predicting diseases even before symptoms occur and turning terminal illnesses into manageable or curable ones" (Johnson et al. 2021). An example of a promising project is the one of a long-acting injectable (LAI) Olanzapine, developed by Medincell in partnership with Teva. Currently in phase 3 clinical trials, the last step before possible approval for adults with schizophrenia. Injected under the skin, it gradually diffuses into the body over several days, weeks, or even months, depending on the patient's needs, offering an alternative to oral medication (Teva 2024). Notably, 60% of patients diagnosed with schizophrenia discontinue their treatment within the first 6 months, in most cases leading to serious relapses that require hospitalization (Berna et al. 2023). The introduction of Olanzapine could revolutionize treatments by guaranteeing stable drug administration, thus reducing the risk of relapse when treatment is stopped. By maintaining constant levels of the drug in the body, this type of therapy

could significantly improve the quality of life of patients suffering from an often underestimated but profoundly disabling condition. As we embrace these advancements, we draw closer to a future where healthcare is tailored to each patient's unique needs. In the words of John C. Lechleiter, “The power in tailored therapeutics is for us to say more clearly to payers, providers, and patients: ‘This drug is not for everyone, but it is for you.’ That is exceedingly powerful” (“The Personalized Medicine Report,” n.d.).

2.4. Economic Implications and the Evolving Role of the Pharmaceutical Industry

2.4.1. Economic Implications of Biotechnological Innovations in Personalized Medicine and the Pharmaceutical Industry's Role in Integration

The integration of innovative biotechnology into personalized medicine has significant economic implications for the PI, which encompasses R&D, manufacturing, and commercialization (“The Personalized Medicine Report,” n.d.). In 2023, pharmaceutical revenues reached approximately USD$1.6 trillion, with biotechnology representing 40% of global pharmaceutical sales. This percentage is projected to increase to 46% by 2030 (Mikulic 2024a). Additionally, the global market for personalized medicine in the PI was valued at USD$529.28 billion in 2023, with NGS recognized as the key factor driving this growth (Grandviewresearch, n.d.). This highlights the increasing relevance and focus of advanced technologies in shaping the future of healthcare. Consequently, the pharma industry plays a crucial role in integrating these advancements into healthcare systems. As stated in an article by McGaughan and Paschalidis (2024), “Personalized medicine is quite possibly the greatest healthcare innovation of our time”. However, as the authors expressed, healthcare providers are not currently equipped to “order, receive, and deliver these new drugs and therapies”. Thus, the PI’s role is to drive this change through collaboration with various stakeholders, including researchers, clinicians, regulators, and industry partners (Laboratorios Rubió 2024). To

effectively integrate innovative therapies and medicines into healthcare systems, the PI must fulfill several key roles. This includes partnering with biotech companies to drive innovation and develop new therapies, which are essential for advancing medical science (Nial 2024). This collaboration enables biotech companies, known for their agility and innovative research, to leverage the financial resources, global reach, and regulatory expertise of big pharma (Laboratorios Rubió 2024).

Additionally, pharmaceutical companies serve a significant role in regulatory advocacy, as they often have more expertise in navigating complex approval processes than biotech companies. They are well-versed in working with agencies such as the US Food and Drugs Administration (FDA) and the European Medicines Agency (EMA), which are responsible for ensuring the safety, efficacy, and security of drugs for human use before allowing market entry (Stirling 2024). Finally, big pharma companies must ensure they stay ahead of regulatory changes (Noonan 2024). Once clinical trials have been completed and regulatory approval is obtained, pharmaceutical companies must focus on commercialization to ensure the market success of PM therapies and medicine.

2.4.2. Shifting Business Model

As stated in an article from the Harvard Business Review on the promises of personalized medicine, “Large pharmaceutical companies have little choice but to change. Those that stick with the blockbuster model face a frustrating future of declining sales and profits.” (2007). However, this transition to a targeted approach is not without its challenges. Pharmaceutical giants, historically attached to the “blockbuster” model that has been a pillar of profitability for decades, have often been reluctant to move away from it (G. Aspinall and G. Hamermesh 2007). The transition to a targeted drug model may initially result in lower sales and profits as companies invest in biomarker discovery, diagnostics, and innovative treatment options. However, the long-term benefits of this approach could far outweigh any temporary

setbacks. Companies that effectively integrate diagnostics into their R&D processes, as well as into its trial design and clinical implementation, will not only strengthen their financial performance but also earn the trust and loyalty of patients and healthcare professionals (G. Aspinall and G. Hamermesh 2007). The imperative for pharmaceutical companies is to adapt. Failing to do so could lead to the risk of becoming obsolete. Therefore, embracing innovative biotechnologies and moving to a service-oriented business model, as well as integrating PM, is the key to thriving in the future of healthcare (McGaughan and Paschalidis 2024). For instance, we can see today that the top big pharmaceutical are the ones that have significantly integrated biotechnology with a strong focus on PM, such as Johnson and Johnson with annual revenues of $85.2bn, La Roche ($66.4bn), and Merck & Co ($60.1bn) (Maragkou 2023).

2.4.3. Challenges & Limitations

Although innovation in biotechnology for PM is experiencing unprecedented growth, it is not without its challenges, and the implementation of PM faces significant obstacles and limitations that prevent widespread adoption and scalability. From the existing literature, we have identified three key challenges for personalized medicine.

Costs and Accessibility: The R&D for PM approaches is more costly than traditional medicine since it necessitates additional diagnosis procedures and genetic testing (Anastasi 2018). For instance, the cost of CAR-T therapy, defined by the National Cancer Institute as used to treat certain blood cancers by changing immune system cells to attack cancer cells (Appendix 13), can exceed US$350,000 per dose, a price that is inaccessible for a significant portion of the population (Caring Cross 2024). Additionally, securing reimbursements from insurance companies for these advanced treatments is most likely to pose a significant challenge ,(National Library of Medicine 2022). Furthermore, this accentuates the economic inequalities in the healthcare systems of low and middle-income countries and creates disparities in access to such therapies (Badr, Abdul Kader, and Shamayleh 2024). In the long term, however,

personalized medicine has the potential to reduce overall healthcare costs significantly (Nardini et al. 2024).

Ethical & Confidential Issues: One of the main challenges of PM lies in confidentiality concerns, as it necessitates collecting a large amount of patient data (Badr, Abdul Kader, and Shamayleh 2024). In today's highly digital age, information circulates in seconds, and medical data is often stored in various institutions, such as hospitals and medical centers, which are then shared between several parties. Furthermore, each institution applies different security protocols, accentuating the risks involved in protecting sensitive data (Mixides 2023). This happened to 23andMe, an American genetics testing company, which had to pay a $30 million lawsuit for having hackers target the company to gain access to the personal information of around 6.9 million of their patients, including sensitive genetic data to post and sell it on the dark web (Stempel 2024).

Clinical Adoption: Lastly, the clinical adoption and approval of biotechnologies, especially in PM products, can be a lengthy process. It often involves long development phases that may take more than a decade and cost billions of dollars, up to 2.6, until they reach the market, all of which can occur without generating profit (Meyer 2024). Additionally, many biotech start-ups rely heavily on external financial support, such as investor funding, in order to develop such complex and innovative therapies. Even once these companies progress to the later phases of clinical trials, the potential failure remains high, with nearly 90% of projects failing between Phase I and the final approval decision, resulting in the jeopardizing of years of work and significant financial investments (Meyer 2024).

3. METHODOLOGY

3.1. Research Design

This research uses a descriptive cross-sectional design combining both quantitative and qualitative methods to explore the relationship between levels of familiarity with PM. Mixed methods research is considered beneficial in health science due to the multifaced nature of the topic studied (Östlund et al. 2010). This study assesses perceptions regarding PM's development, barriers, strategies, and role in the healthcare sector. Conducted with ethical considerations, the research focuses on the perception of students, graduates, and professionals in biomedicine-related fields to draw insights regarding their expectations of PM's future trajectory.

3.2. Data Collection Process

The data for this study was gathered using a survey administrated through Qualtrics XM (Appendix 14). The questionnaire was initially distributed via multiple platforms, such as Messenger, LinkedIn, and through word of mouth, to implement a snowball sampling method targeting niche populations. This method relies on participants recruiting others, making it particularly suited for exploratory research on specialized or hidden groups (Bell, Bryman, and Harley 2022). The survey included multiple-choice questions, 1-5 Likert scales, ranking questions, and a final open-ended question that allowed participants to provide more detailed information about their views on the most promising biotech innovation driving PM. However, to enlarge the sample size and gather additional responses, the survey was subsequently shared on Prolific, an online platform designed to connect researchers with quality participants. On Prolific, participants were selected based on their educational and professional backgrounds in fields such as Health and Medicine, Pharmacology, Biochemistry, and Biological and Biomedical Sciences, ensuring a reliable sample group. In total, 108 participants responded, the sample characteristics are detailed in Appendix 15 and conducted across 14 countries (Appendix 16), providing a more comprehensive view of how PM is perceived globally.

The survey was divided into four blocks, in line with the study's objectives. The first block was designed to collect demographic and general information, such as age, gender, and level of education, to understand the profile of the participants. The second block was used to assess familiarity with PM by asking participants to indicate their level of knowledge on the topic. Based on their answers, the participants were then divided into three groups: 'Less familiar' (not familiar or slightly familiar), 'Knowledgeable' (moderately familiar), and 'Familiar' (very familiar or extremely familiar). This categorization was crucial to the reliability of the statistical analyses due to the initial small sample size to strengthen the results on how different levels of familiarity influenced perceptions. The third block focused on perceptions of biotechnological contributions to PM. Participants were asked to identify the technologies they considered most important and to rank the therapeutic areas most affected by PM. The final block explored participants' views on the future of its trajectory by identifying barriers to its widespread adoption and strategies to overcome these challenges.

3.3. Data Analysis

The data analysis was structured to address the following research question: **RQ**: 'Where is personalized medicine likely to position itself in the healthcare sector in the short and medium term? What are the main trends shaping the development of personalized medicine? How can the sector overcome the challenges hindering its widespread adoption?'

Hypotheses were formulated to determine whether familiarity with personalized medicine influences perceptions. PM, being an emerging and still uncommon practice, gives rise to varied opinions influenced by the degree of knowledge and understanding of the underlying concepts. This allowed the research question to be answered by isolating the views of the familiar group.

The hypotheses tested are as follows:

- **H_0:** Familiarity does not significantly influence perceptions of the future impact of personalized medicine, key trends, and challenges.
- **H_1:** The degree of familiarity significantly influences perceptions of the future impact, key trends, and challenges of project management.

The raw responses were first organized and cleaned using Excel to prepare the data for analysis, where six invalid data sets were removed. The cleaned data was then imported into SPSS, which was used for the statistical analysis. Cross-tabulations and chi-square tests were applied to determine whether familiarity levels significantly influenced participants' perspectives on the role of PM. These tests were used to accept or reject the null hypotheses. Lastly, column tables were created through Excel to visually represent the results of participants' familiar perceptions and draw a final conclusion to the RQ.

4. RESULTS

4.1. The Role of PM in Healthcare

The participants demonstrated a generally high level of familiarity with the term PM. Only four reported not being familiar at all, while 15 indicated they were only slightly familiar. Demonstrating an overall comprehension of the topic among the sample. When asked about beliefs in PM to replace the traditional “one-size-fits-all” approach, the cross-tabulation results (Appendix 17) underscore that more informed participants tended to have greater optimistic expectations, with ‘familiar’ and ‘knowledgeable’ individuals responding ‘probably yes’ (40.4% and 53.1%, respectively). The ‘less familiar’ participants, on the other hand, were more mixed, with a relatively high proportion opting for ‘probably yes (36,8%) but also expressed some doubts (‘probably not’, 31.6%). Even though these results may appear indicative of a difference in perspectives among the groups, the Chi-square test ($p=0.058$) showed no statistically significant relationship between familiarity and the beliefs expressed (Appendix

18). Therefore, even though familiarity could influence perceptions of PM, this influence remains limited in this specific context, and further analysis from a larger sample might provide more conclusive evidence.

Regarding the anticipated timing for the impact of PM, the cross-tabulation (Appendix 19) reveals that 42,1% of respondents who are 'less familiar' with the topic expect a mid-term adoption period of 10-20 years while the remaining respondents were split evenly, with 21,1% believing in both short-term adoption (5-10 years) and long-term (20-30 years). In comparison, who are 'familiar' with PM displayed a slightly more consistent view, with 40,4% believe in a medium-term adoption period of 10 to 20 years, while 26,3% foresee standardization within 5 to 10 years. The 'knowledgeable' group showed similar trends, with 28,1% expecting short-term adoption and 37,5% favoring mid-term. The data highlights a general consensus among participants, as indicated by the Chi-Square test results ($\chi^2(8) = 4.851$, $p = 0.773$) which did not reveal a statistically significant link between familiarity and estimated timelines (Appendix 20). However, it is worth noting that none of the respondents, regardless of their familiarity, selected the option indicating that PM would not be adopted, reflecting a collective optimism about its successful integration into the healthcare system.

When exploring participants' views on the future role of PM in healthcare, the Crosstabulation (Appendix 21) reveals some interesting trends regarding the influence of familiarity level on perceptions. For instance, 35.1% of 'familiar' participants and 37,5% of 'knowledgeable' believe that PM will play a transformative role, compared to 15.8% of those who are 'less familiar'. This suggests that a higher level of familiarity could be assimilated into a more favorable opinion about PM's potential to disrupt the healthcare industry. However, the majority of respondents (>50% across all familiarity groups), indicate that they believe PM will play a more incremental role, coexisting alongside traditional medicine. Only 13% of participants feel that its role will be limited, reflecting widespread confidence in PM's future

potential. Interestingly, 'less familiar' participants are more inclined to view its role as limited (21.1%) compared to both 'knowledgeable' (9.4%) and 'familiar' (12.3%), suggesting a more cautious attitude among the less informed. However, although the responses seem to differ based on familiarity levels, the Chi-Squared test ($\chi^2 = 3.607$, $p = 0.462$) did not reveal a statistically significant association between familiarity and responses (Appendix 22). This suggests that the observed variations observed could be due to hazard rather than a concrete relationship.

Although the Chi-squared tests reveal no statistically significant difference between familiarity levels and perceptions of the future impact of PM, as indicated by p-values exceeding the conventional threshold of 0.05, we are unable to reject the null hypothesis (H_0). Further research with larger samples may validate these observations. Finally, to draw meaningful conclusions related to the RQ, we focused solely on the insights of the most familiar participants throughout the entire results analysis to provide insights based on their greater informed perspectives. From the clustered data (Appendix 23, 24 & 25) we can conclude that PM is likely to coexist alongside current medical practices. However, it has the potential to transform the traditional "one-size-fits-all" approach to treatment, with an anticipated impact within a timeframe of 10 to 20 years. Ultimately, we can conclude that the recognition of the role of PM is growing, and it is becoming a crucial element in shaping the future of healthcare and its evolving position within the healthcare industry.

4.2. Key Trends Shaping PM

To gather insights regarding the different perceptions of the most significant contribution of biotechnology to PM included several options, including 3D bioprinting, AI in drug discovery, biobanks, CAR-T therapies, CRISPR gene editing, molecular diagnostics, NGS, and wearable devices (Appendix 26 provides a brief explanation of these biotechnologies). The crosstabulation (Appendix 27) shows varied preferences across

familiarity groups; ‘less familiar’ participants were more inclined to choose “CRISPR” at 22,4% as the most significant contribution, and ‘knowledgeable’ and ‘familiar’ opted for NGS at 24,4% and 21,6%. However, the respective technologies were widely recognized as making an important contribution to PM within all familiarity groups, showcasing that opinions did not vary significantly according to their level of knowledge or experience. Conversely, 3D bioprinting (5.1%), AI for drug discovery (5.1%), and wearable devices (7.9%) are among the least frequently mentioned contributions across the three groups, highlighting their perceived more marginal role in the current PM landscape and accentuating the unanimous agreement regardless of familiarity levels. Additionally, biobanks were moderately preferred by “familiar” and “knowledgeable” participants, with 11.4% and 10.1% respectively, while for “unfamiliar” participants, it was the least preferred option, at 5.2%. The Chi-squared analysis (Appendix 28) indicates no statistically significant relationship between the degree of familiarity and the selected contributions (χ^2= 4.423, p-value of 0.992).

Participants were then asked to rank the therapeutic areas that they believe have benefited the most from innovative biotechnological advancements in PM. When ranking between oncology, neurology, infectious diseases, cardiovascular diseases, rare genetic disorders, and metabolic disorders, the results revealed notable trends according to familiarity levels (Appendix 29). Oncology emerged as the most frequently ranked field at 46,3% within all familiarity areas, particularly in the 'familiar' group, where almost half (49.1%) ranked it first. Followed by infectious diseases in second place for all familiarity groups at 31,5%. This underscores the vital role of integrating PM biotechnology innovations in oncology and treating infectious diseases. In contrast, neurology was ranked sixth, with 28.1% within the familiar group. Whereas the ‘knowledgeable’ and ‘less familiar’ group positions metabolic disorder on the 6th place with 31,3% and 31,6% respectively, suggesting that these areas have not yet fully benefited from advances in biotech. This time, the Chi-squared test (Appendix 30) results (χ^2 =

162.556, $p < 0.001$) revealed a statistically significant association between familiarity and ranking preferences, indicating that perhaps, in this case, familiarity is crucial in shaping perceptions of innovative biotech solutions within therapeutic areas. However, this could also be related to the greater variability in responses since ranking multiple items reduces the likelihood of homogeneity compared to other questions with fewer or more restricted choices. This reinforces the argument that a larger sample is needed for more accurate and reliable results.

The findings lead to mixed conclusions regarding the hypothesis. Regarding key biotechnology contributions, the null hypothesis (H_0) cannot be rejected, as familiarity does not appear to significantly influence perceptions. On the other hand, for therapeutic areas, the null hypothesis is rejected, indicating that familiarity potentially plays an influential role in responses. These findings highlight the importance of familiarity in understanding the impact of PM and suggest that further research with more extensive and diverse samples is essential to validate these trends and uncover further insights. To answer the RQ on key trends, the clustered tables (Appendix 31) reveal that participants with greater knowledge of PM showed stronger preferences for NGS, CRISPR, and molecular diagnostics, reflecting their greater understanding of the significant impact of these technologies. Moreover, in the open-ended question (Appendix 32) when asked about the most promising biotech innovation for PM, 34% mentioned CRISPR as a "*tool enabling targeted correction of genetic mutations that cause diseases such as sickle cell anemia or certain cancers."* aligning with what has been seen in literature review.

In addition, CAR-T therapies and biobanking, although less frequently selected, are recognized as emerging innovations with growing potential. Notably, respondents consistently ranked oncology as the main area benefiting from biotech innovations, reflecting their awareness of the substantial progress being made in this area.

4.3. Challenges Hindering the Adoption of PM and Strategies

The crosstabulation analysis (Appendix 33) regarding the key barriers to implementing innovative biotechnologies in PM reveals some interesting trends. Among the most frequently mentioned barriers, 'high R&D costs' emerged as the primary obstacle (28.2%) for all groups, with a notable difference compared to the second most chosen barrier. However, variations emerge among different participant groups for other barriers. 'Knowledgeable' and 'less familiar' participants were more inclined to select 'ethical concerns' as their second choice (15.8% and 19.0%, respectively). In contrast, 'knowledgeable' participants emphasized on 'public skepticism or misinformation' (17.2%) as hindering PM's adoption. This perspective is not shared by the others, as 'familiar' and 'less familiar' respondents recorded only 8,2% and 6,9%, putting it as the least urgent barrier. The barriers cited less frequently by all participants include 'intense competition in the biotechnology industry,' recognized by only 5%, and 'strict regulations,' noted by 7.9%. These statistics suggest that these factors are not considered major obstacles to the integration of PM, highlighting a generally uniform perception regardless of familiarity levels. Although some variations are noted, the Chi-square test produced a p-value of 0.317, suggesting no statistically significant relationship between familiarity levels and the identification of barriers (Appendix 34). This indicates that the groups generally share similar opinions.

Participants were subsequently asked to select the strategies they considered most critical for overcoming the obstacles to implementing PM (Appendix 35). The crosstabulation results revealed that all strategies received similar percentages, with the highest gap being only 10,3% for 'public skepticism' between the 'knowledgeable' group at 17.2% and the 'familiar' group at 6.9%. Most respondents in each category identified two specific strategies as particularly relevant: 'government funding for R&D in biotech' (28.3% overall) and 'improved collaboration between biotech companies and healthcare systems' (23.1%). Conversely, the

least favored strategies were ‘streamlining regulatory processes to speed up approval timelines’ at 10.2% and ‘leveraging AI to enhance R&D’ at 10.8%. These strategies appear to be viewed as lower priorities for promoting PM’s adoption among participants. Furthermore, strategies like ‘standardizing international regulations’ and ‘accelerating regulatory approval processes’ received comparable levels of acknowledgment (14.5% and 13.2%, respectively), indicating a more moderate awareness of their importance compared to the most favorable ones, yet showing minimal variation from the strategies that received the lowest rates. The perspectives of the groups were once again quite similar, as indicated by the Chi-square test ($\chi^2 = 1.570$, $p = 0.999$), which demonstrated no statistically significant relationship between familiarity levels and probability of selecting strategies (Appendix 36).

The Chi-square test for both barriers and strategies found no statistically significant relationships between familiarity levels and participants’ responses. The overall data shows homogeneity, leading us to retain the null hypothesis. To answer the RQ, the primary barrier identified for adopting biotech in PM was the ‘high cost of R&D’ (Appendix 37). Moreover, when discussing strategies, (Appendix 38) respondents emphasized two main approaches: increasing government funding for R&D and fostering better collaboration between biotechnology companies and healthcare systems.

5. Discussion

5.1. Theoretical implication

The study examined whether views on PM varied by levels of familiarity. The results revealed little evidence of a relationship, indicating a shared understanding and perceptions of the current and future state of PM among the groups. This may reflect the growing public awareness and education on the topic, even among ‘less familiar’ participants. Additionally, 17% reported knowing someone or having experience with PM, while 30% answered ‘maybe’.

This could imply a potential increase in the adoption of PM practices, consistent with research showing that over the past four years, more than one-third of the drugs approved by the FDA have been personalized medicines, a number expected to rise (McGaughan 2024). Research supports that PM is an innovative strategy capable of reshaping the conventional healthcare model. This is supported by the CEO of PhRMA, who cited that "Personalized medicine stands right at the center of the health care revolution, with the science enabling greater precision that not only can improve the lives of patients but can also create efficiencies within the health care system by delivering the right treatment to the right patient at the right time" ("The-Personalized-Medicine-Report1.Pdf," n.d.). The study revealed dual perspectives among respondents. On one side, nearly half believe in the PM's transformative ability to dominate healthcare, while the other half view its impact as more incremental. Existing research (Dimitri, Herbst, and Fraietta 2022), however, argues that although PM is emerging as a disruptive approach, its integration is likely to be gradual and coexist with conventional health systems. However, the successful integration of PM would necessitate a significant shift in the PI's existing business model, as highlighted by research (Jones et al. 2024) and discussed in the literature review.

Innovative biotechnologies such as NGS, CRISPR, and CAR-T are perceived as key emerging enablers of PM, according to numerous studies (Macarrón Palacios et al. 2024) (Dimitri, Herbst, and Fraietta 2022). These trends, largely supported by the literature, are also confirmed by our findings, which identify them as significant contributions to PM. Regarding the perceived therapeutic areas that most benefit from these innovations, Oncology was largely selected among the participants, aligning with a substantial number of existing studies that affirm that personalized medicine has made a significant impact in oncology more than in any other medical field (Ciardiello et al. 2014)

However, PM's adoption faces notable challenges. Research has identified numerous obstacles for patients, institutions, and healthcare professionals. However, the challenges regarding its integration, such as “global integration,” “ethical considerations,” “adoption hurdles,” and “regulatory and governance limitations,” are often cited (Goetz and Schork 2018b) (Dharani and Kamaraj 2024; Cinti et al. 2024). Our results differ slightly from these conclusions, with participants identifying the high cost of R&D as the main challenge to PM implementation. While existing research highlights strategies such as ‘ensuring access to care,’ ‘recognizing value,’ and ‘education and awareness’ (Pritchard et al. 2017). The findings emphasized the importance of ‘increasing public funding for biotechnology R&D’. Strategies such as ‘improving public education’ and ‘streamlining regulatory processes’ were among the least selected, suggesting they are seen as less immediate priorities. However, ‘standardizing international regulations to facilitate global uptake’ aligns with existing research, reflecting its recognized importance in advancing PM.

Lastly, prior research by Garfeld et al. (2015) indicates that individuals diagnosed with a life-threatening condition are more inclined to consider PM (Garfeld et al. 2015). This aligns with our findings, where 77% of participants believed that the high costs of PM were justified by its benefits. Suggesting that when faced with a serious illness, people are often willing to pay the price. Bringing hope to those suffering from diseases that are unable to be treated or hardly by conventional medicines or therapies.

5.2. Practical implications

This study's findings offer important insights into how pharmaceutical firms can leverage innovative biotechnologies to enhance precision medicine (PM) and confront existing challenges. Collaborating with emerging biotech companies allows for a fusion of their agility and innovation with the financial backing and regulatory know-how of larger pharmaceutical

firms. It is also crucial to address cost barriers to promote the widespread adoption of PM. Firms should consider strategies to manage high R&D costs, such as fostering public-private partnerships, securing government funding, and refining production methods to reduce treatment costs. Cost-effective options will enhance access to PM, reduce inequalities, and expand patient benefits.

By implementing these strategies, pharmaceutical companies can establish themselves as frontrunners in the future of healthcare, effectively surmounting obstacles to PM while providing suitable, effective, and accessible treatments for patients globally.

6. Limitations and direction for future research

This study has several limitations that should be acknowledged. Firstly, while the research aimed to capture nuanced views on PM, the differences between participant groups were less pronounced than anticipated. Several factors contribute to this. First, although the sample size was diverse, it remained relatively limited. A larger sample size could contribute to more accurate and credible conclusions and help detect smaller effects or differences that might not be visible with a limited sample, thereby improving the statistical power of the analysis. For instance, the results of the chi-square tests in the analysis, in some cases, were affected by the violation of assumption 4, which stipulates that the expected value of the cells must be equal to or greater than 5 in at least 80% of the cells. This assumption was not always met, impacting the reliability of the chi-square, subsequently affecting the accuracy of the conclusions drawn. This limitation highlights the need for larger sample sizes in future studies to ensure the validity of the statistical tests and to obtain more robust results.

Moreover, more noticeable variations in familiarity levels might have revealed significant differences in perception since only 4 out of 108 participants were entirely unfamiliar with PM. However, in this case, knowledge about PM was required as failing to do so could have created

misleading responses and, therefore, broken the credibility of the research due to the use of complex terminologies that only informed participants could understand. This suggests that, in our situation, most participants had some prior knowledge of the topic. Furthermore, the questions might have been overly general and lacked specificity, potentially leading to more easily interpreted answers or randomized responses. This could account for the occasionally similar distribution of choices for each possible answer

Additionally, with the rise of the internet, participants can easily look up information related to the survey questions. While there were no definitive right or wrong answers, online access might have influenced participants to provide similar responses. Furthermore, the survey questions, while structured for clarity, offered predefined options, which may have impacted the depth and diversity of responses. Including more open-ended questions could have helped address this limitation. Thirdly, quantifying the data proved to be challenging, as only two questions gathered 1-5 Likert scale responses. A larger and more representative sample would allow for more statistically robust findings, reducing the likelihood of random variability and enhancing generalizability. Moreover, further qualitative data, such as interviews, could have been beneficial. Future studies may benefit from a mixed-methods approach that includes additional interviews or focus groups to explore participants' views in greater detail.

Finally, the scope of the literature review was relatively broad, covering multiple aspects of PM. While this approach provided a comprehensive overview, it may have diluted the focus on specific areas within the field. Future research could benefit from narrowing its scope to explore each aspect of the impact of biotech advancements PM in greater depth.

7. Conclusion

In conclusion, this research confirms that PM is not merely an enhancement of traditional healthcare but a transformative approach with the potential to revolutionize healthcare. By delivering targeted, effective, and safer treatments tailored to the unique characteristics of

individual patients, PM significantly improves patient outcomes, and its true power lies in personalization. Leveraging advances in biotechnology such as next-generation sequencing (NGS), CRISPR gene editing, and CAR-T therapies, offering hope to patients with previously difficult-to-treat or incurable diseases. Oncology has been the most prominent beneficiary of these innovations, but other therapeutic areas, including cardiovascular and neurological diseases, are beginning to realize the benefits of this groundbreaking approach.

However, despite its vast potential, PM faces obstacles, including high research and development costs, limited accessibility to innovative treatments, and the complexities of scaling production. Addressing these obstacles requires a multi-faceted strategy. Key solutions include increasing public funding for biotechnology R&D, fostering collaboration between pharmaceutical companies, biotech start-ups, and healthcare systems, and optimizing production processes to make treatments more affordable and accessible, particularly in underdeveloped countries.

The pharmaceutical industry plays a pivotal role in the successful adoption of PM in the short to medium term. Companies must adapt their business models, embrace emerging technologies, and form strategic partnerships to drive innovation while ensuring compliance with regulatory standards and maintaining financial sustainability. Failure to evolve risks stagnation and obsolescence in a rapidly changing healthcare landscape. Despite the challenges, the future of PM appears promising, with expectations that it will become increasingly accessible and affordable, ultimately transforming the way healthcare is delivered worldwide.

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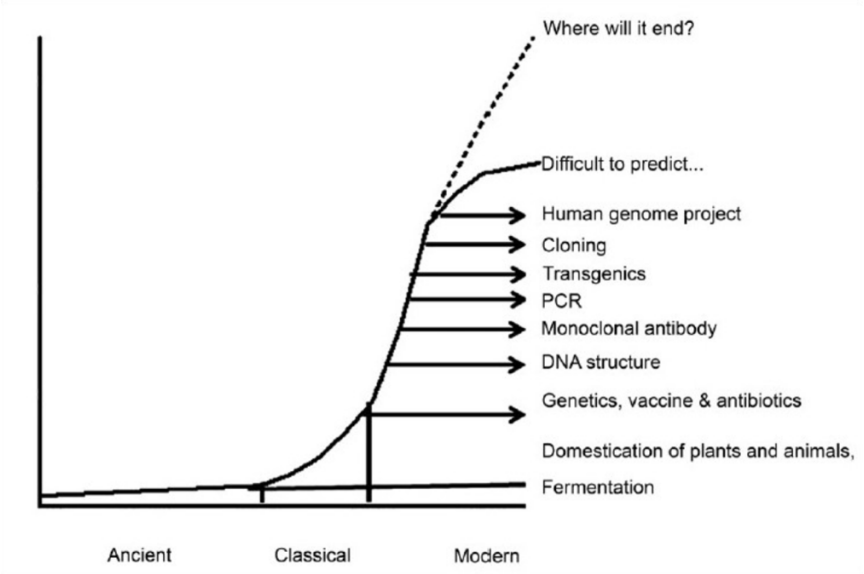
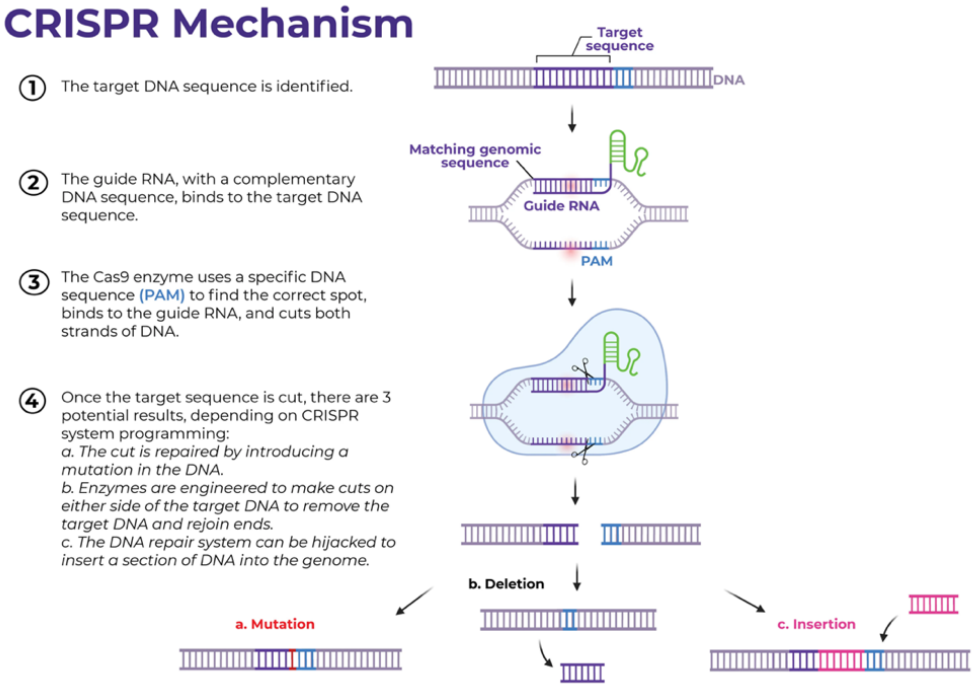
8. APPENDIX

Appendix 1: The Developmental Timeline of Biotechnology



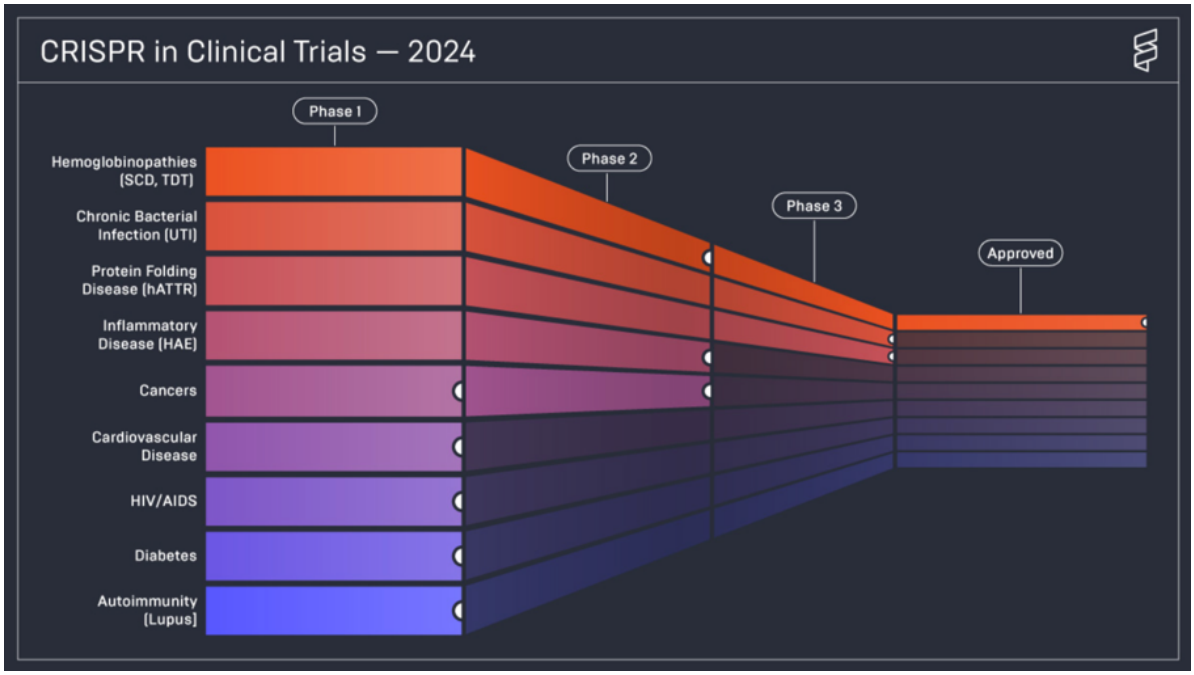
Source: (Alonso, Susel Góngora, Isabel de la Torre Díez, and Begoña García Zapiraín. 2019)

Appendix 2: The Mechanism of CRISPR-Cas9 Gene Editing



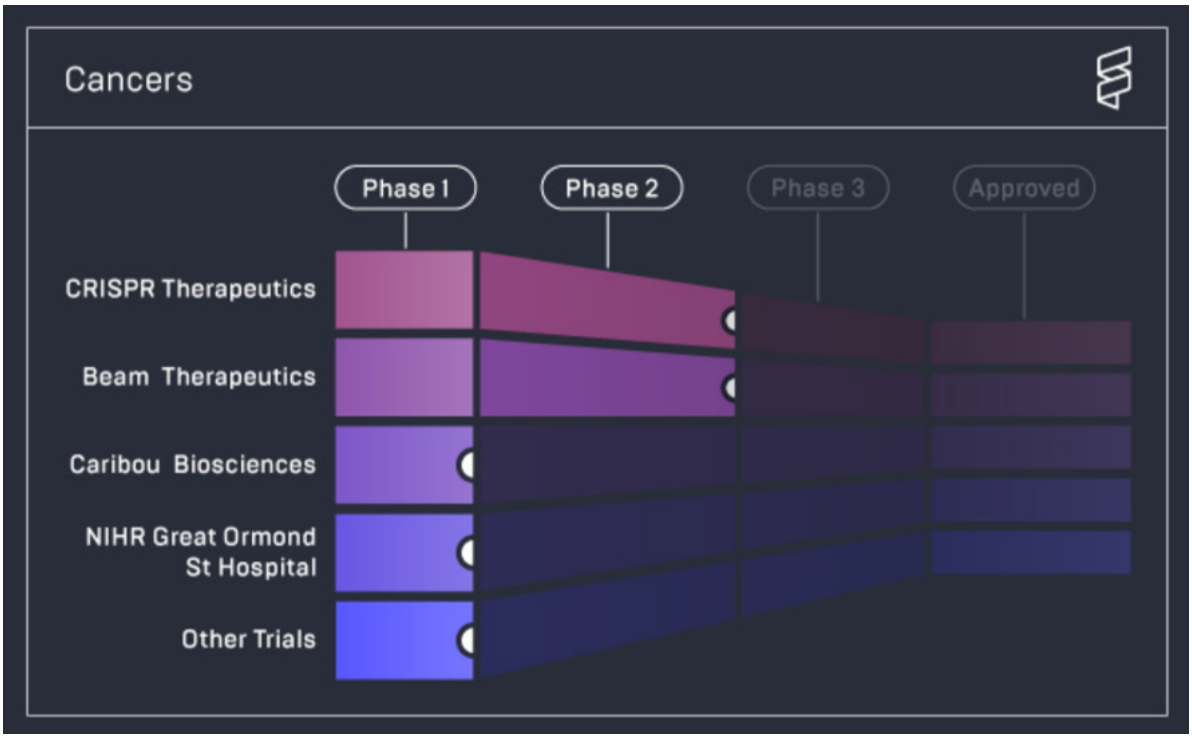
Source : ("What Is CRISPR?" 2021)

Appendix 3: CRISPR in clinical trials 2024



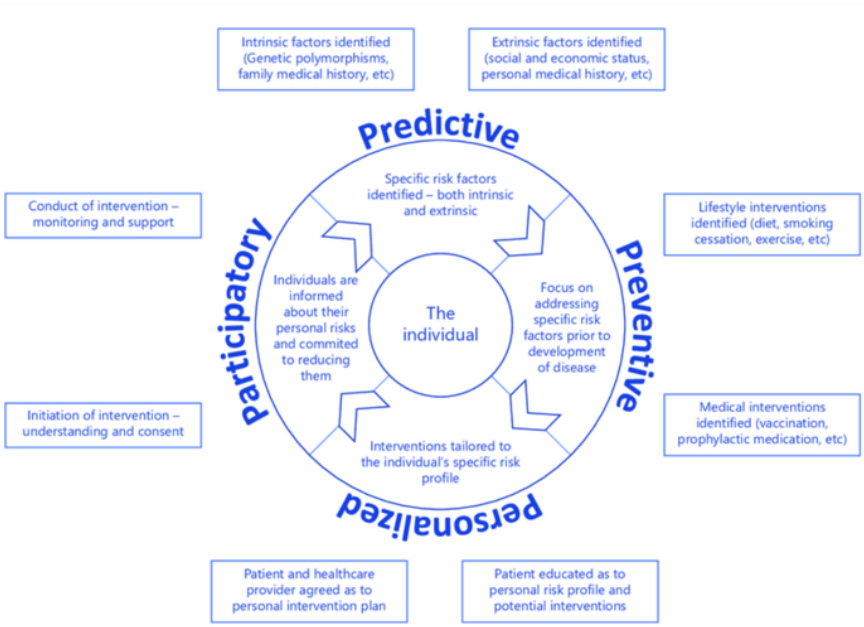
Source : (Henderson 2024)

Appendix 4: CAR-T immunotherapy for Cancer



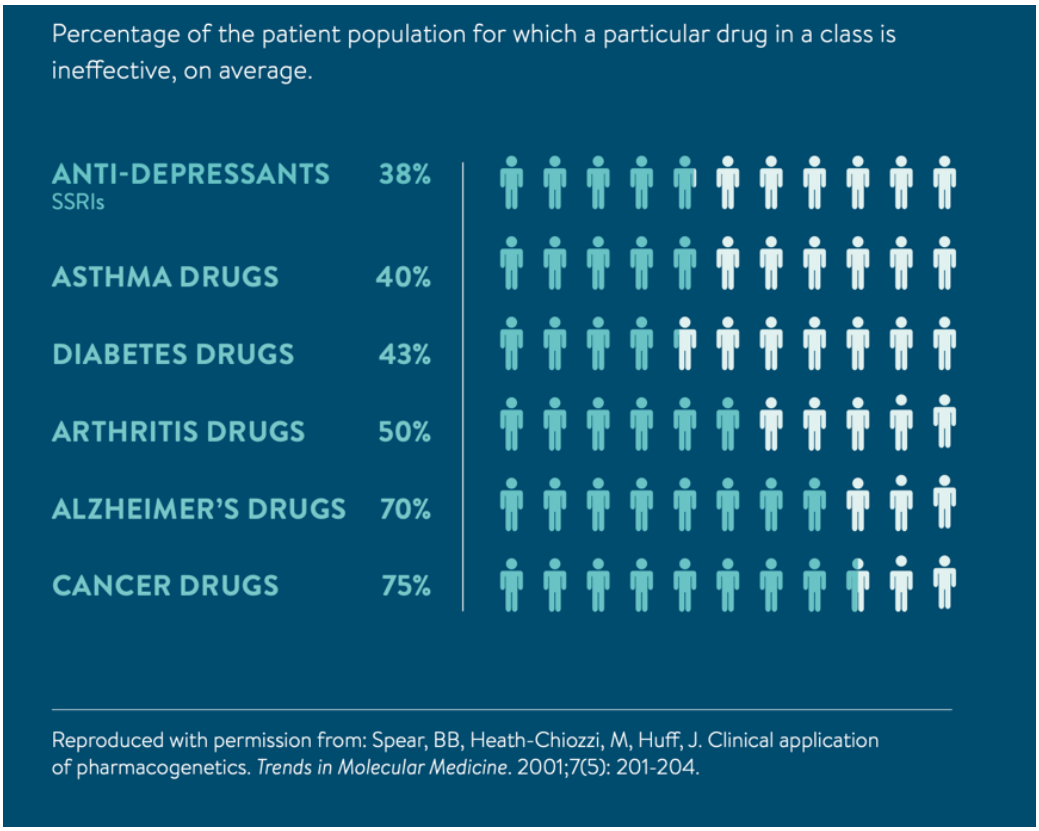
Source : (Henderson 2024)

Appendix 5: The 4P's of PM



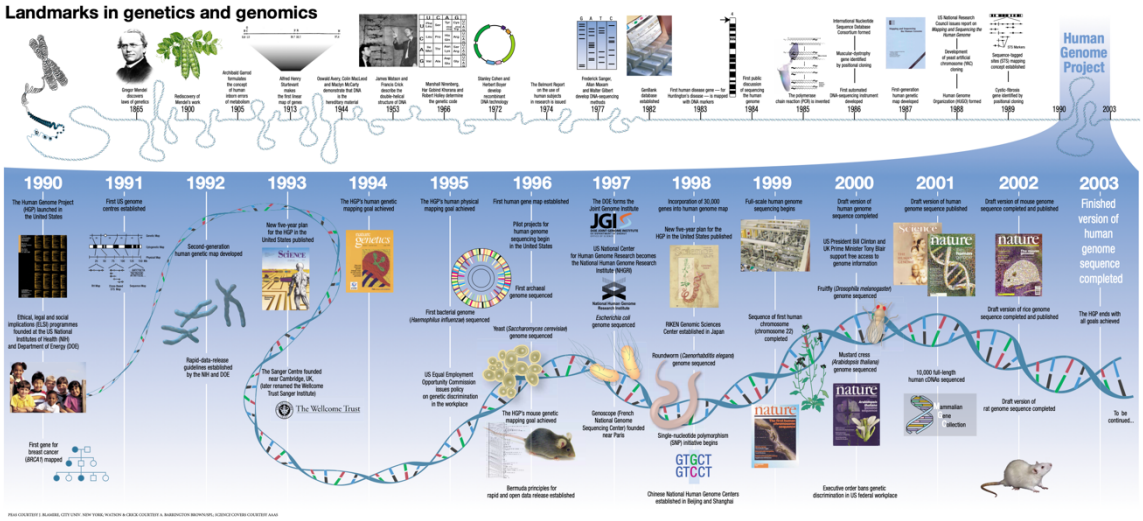
Source: (Doherty et al. 2019)

Appendix 6: One size does not fit all



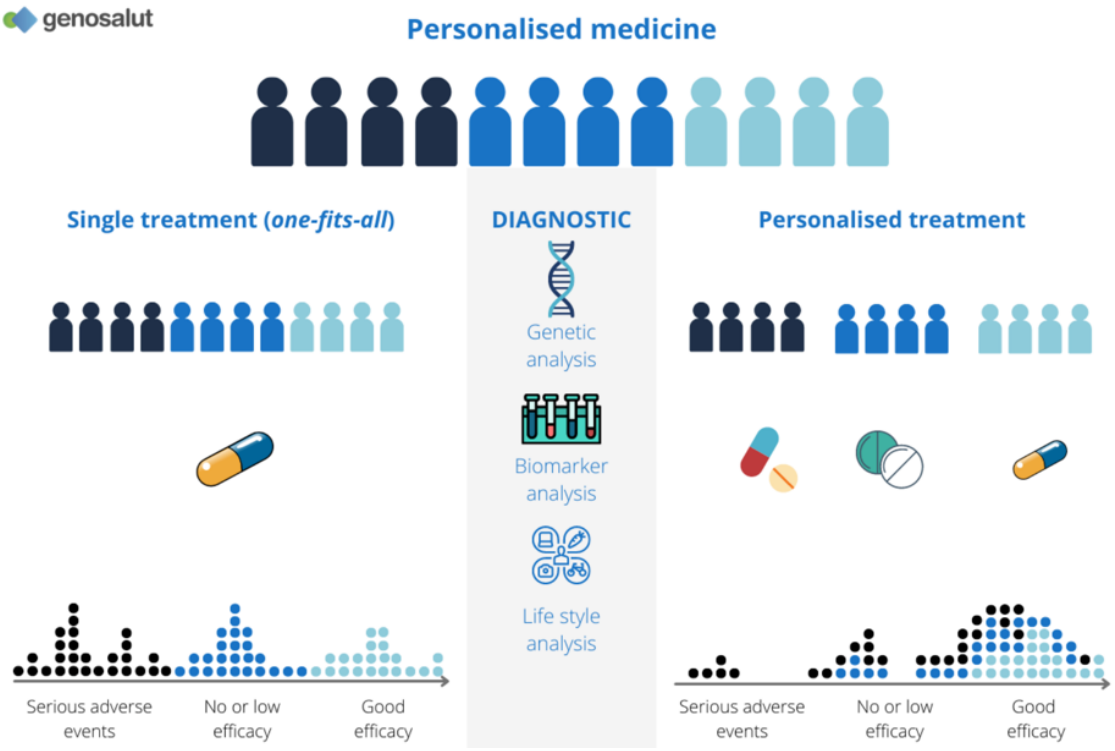
(source: "The-Personalized-Medicine-Report1.Pdf," 2017)

Appendix 7: The Human Genome Project



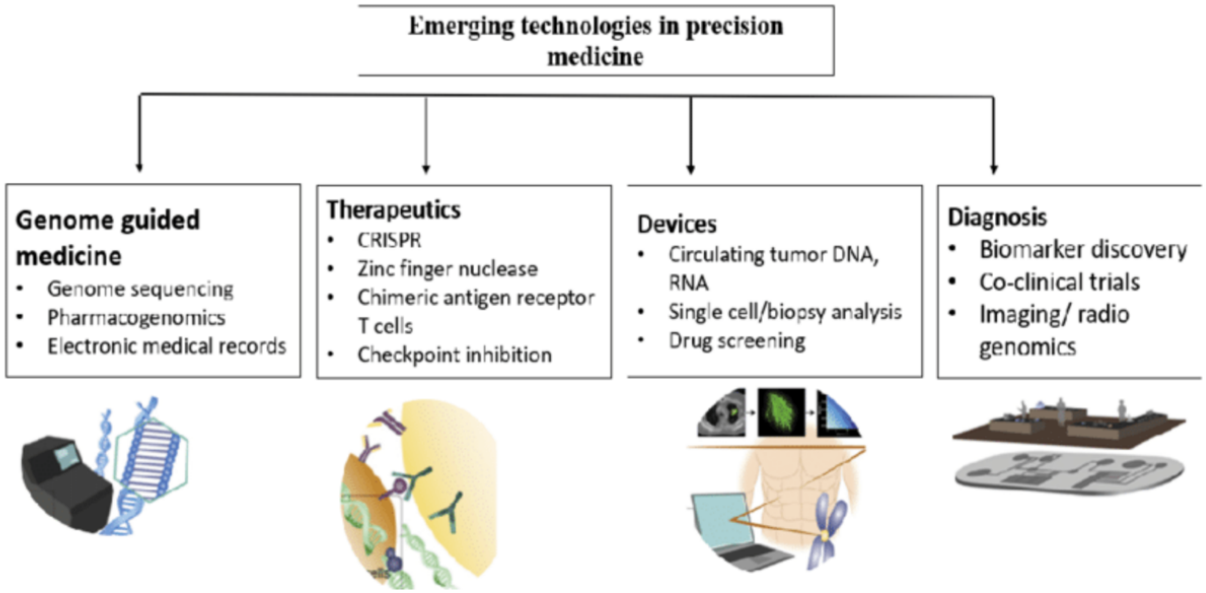
Source: ("The Human Genome Project," n.d.)

Appendix 8: Comparison of Single Treatment vs PM Approaches



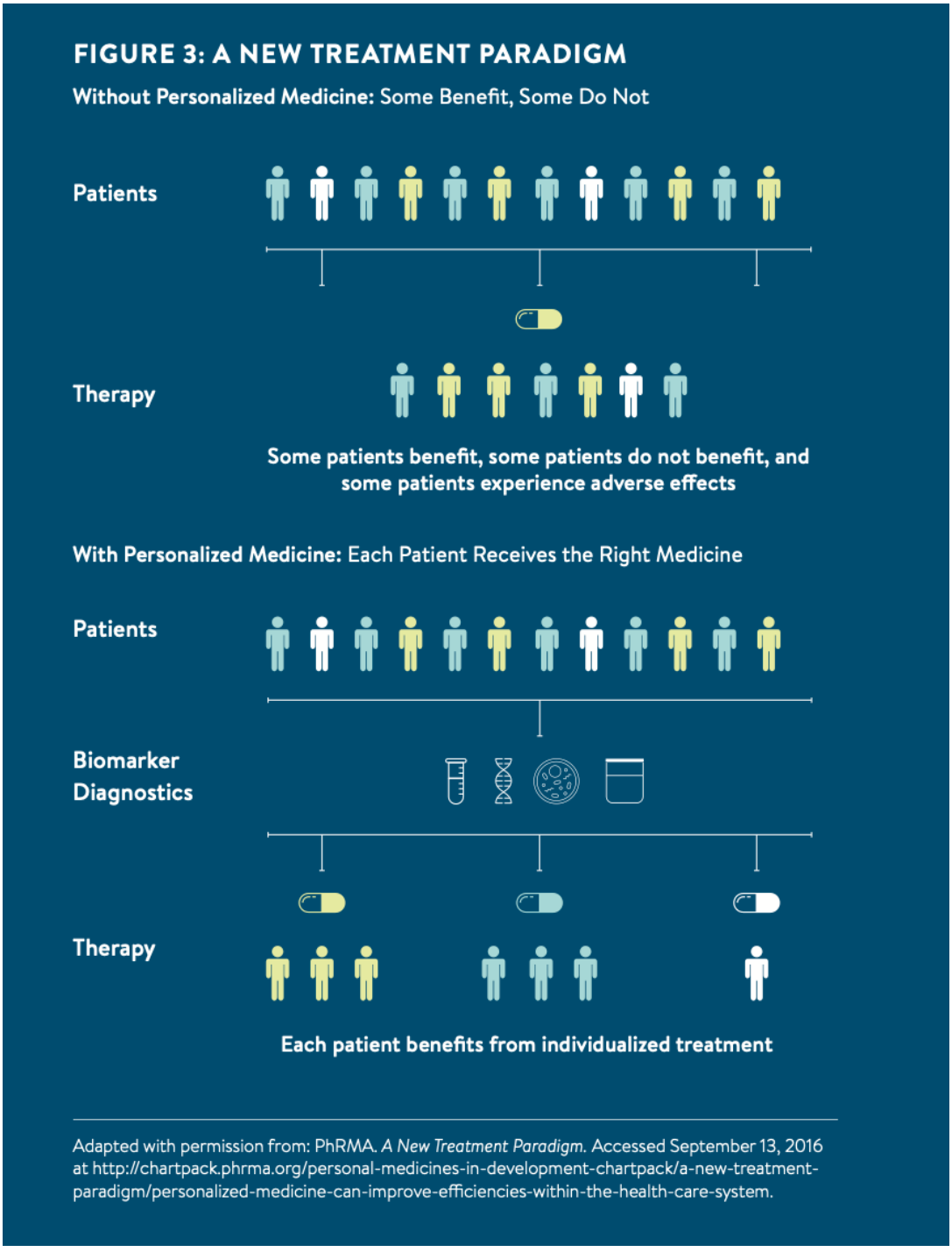
Source: (Genosalut_Palma 2022)

Appendix 9: Emerging Biotechnology Tools and Therapies



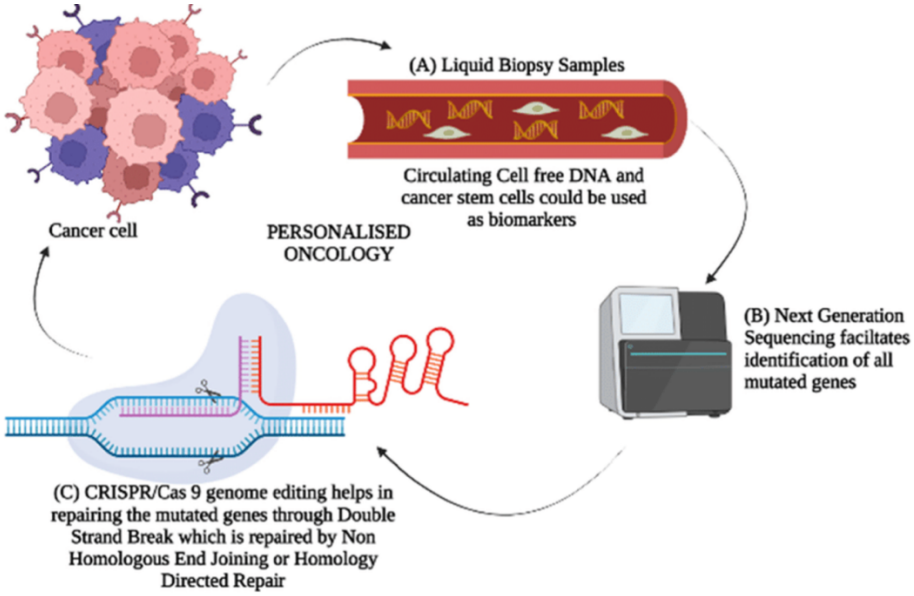
Source: (Prasanthi Nori and Kiran 2021)

Appendix 10: A new Treatment Paradigm



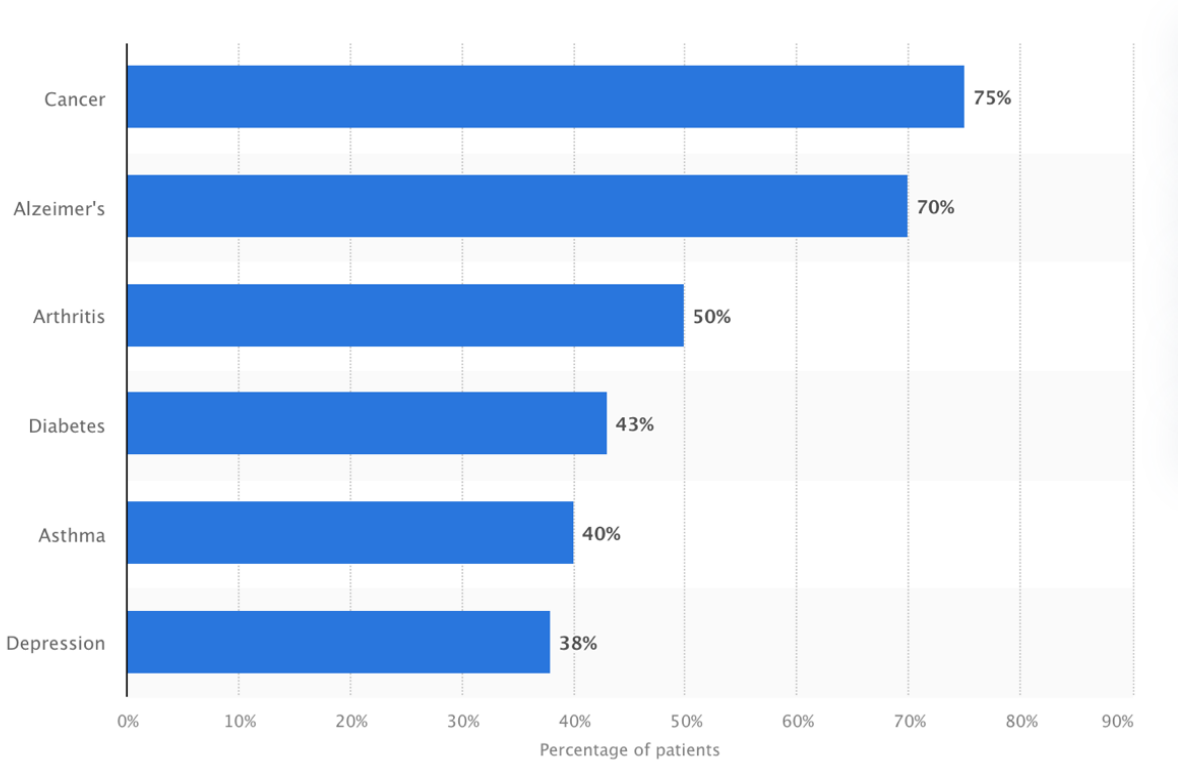
Source: ("The-Personalized-Medicine-Report1.Pdf," n.d.)

Appendix 11: Next-Generation Sequencing (NGS) in the personal treatment of cancer



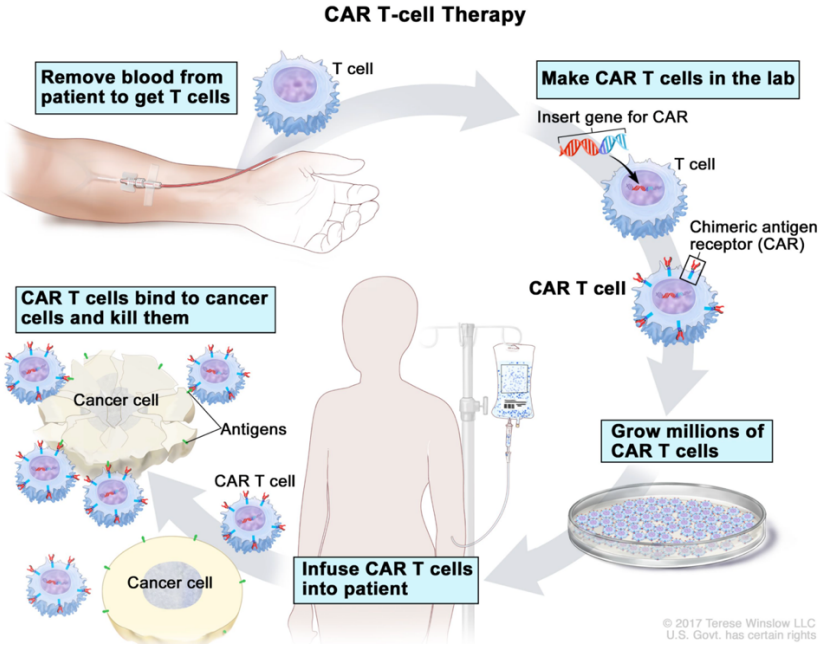
Source:(Selvakumar et al. 2022)

Appendix 12: Percentage of patients for which a certain drug is ineffective by therapy class.



(source: Mikulic 2024c)

Appendix 13: CAR-T cell therapy Mechanism



Source: ("Definition of CAR T-Cell Therapy - NCI Dictionary of Cancer Terms - NCI," n.d.)

Appendix 14: Survey

The impact of innovative biotech on personalized medicine in the pharmaceutical industry

Survey Flow

Standard: Introduction (1 Question)
Block: Background (4 Questions)
Standard: Familiarity with Personalized Medicine (2 Questions)
Standard: Biotechnological Contributions (3 Questions)
Standard: Perceptions and future outlook (3 Questions)
Standard: Barriers, Strategies and Reflections (3 Questions)

Page Break

Start of Block: Introduction

Welcome to my survey! Hi! Thank you for taking the time to participate in this survey, which is part of a research study for my Master's thesis at Nova School of Business and Economics titled "The Impact of Innovative Biotechnology on Personalized Medicine in the Pharmaceutical Industry." This survey aims to gather insights from students, alumni, and professionals biomedicine-related fields to understand their perceptions, knowledge, and views on biotechnology and personalized medicine. Your responses are completely anonymous and will be used solely for academic purposes. Completing this survey will take approximately 7 minutes. If you have any questions about the survey, or if you're interested in exploring this topic further and would like to participate in an interview, please feel free to contact me at 60124@novasbe.pt. Thank you for very much for your time and valuable input!

End of Block: Introduction

Start of Block: Background

What is your gender?

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary / third gender (3)
- ○ Prefer not to say (4)

What is your age?

_____

What is your current level of education?

- ○ Undergraduate (1)
- ○ Master's (2)
- ○ PhD (3)
- ○ Other (please specify) (4) _____

Please select your nationality

▼ Afghanistan (1) ... Zimbabwe (1357)

End of Block: Background

Start of Block: Familiarity with Personalized Medicine

How familiar are you with the concept of personalized medicine (uses a patient's genetics, lifestyle, and environment to create tailored treatments)?

- ○ Not familiar at all (1)
- ○ Slightly familiar (2)
- ○ Moderately familiar (3)
- ○ Very familiar (4)
- ○ Extremely familiar (5)

Have you or someone close to you ever benefited from a personalized medicine approach?

- ○ No (1)
- ○ Maybe (2)
- ○ Yes (if yes, please specify) (3)

_____

End of Block: Familiarity with Personalized Medicine

Start of Block: Biotechnological Contributions

What do you think is the most significant contribution of biotechnology to personalized medicine? (select up to three)

- ☐ Next-Generation Sequencing (NGS) (Technology that quickly reads DNA to identify genetic variations) (1)
- ☐ CRISPR and gene editing (Tools for altering genes to correct mutations or treat diseases) (2)
- ☐ CAR-T cell therapy (A treatment where a patient's immune cells are modified to fight cancer) (3)
- ☐ Biobanks (Collections of biological samples and data used for research and developing treatments) (4)
- ☐ Molecular diagnostics (Advanced tests to detect specific diseases or genetic traits) (5)
- ☐ AI in drug discovery (Using AI to speed up drug development and improve targeting) (6)
- ☐ Wearable devices (Devices that continuously monitor health metrics) (7)
- ☐ 3D Bioprinting (Printing patient-specific tissues and organs) (8)
- ☐ Other (please specify) (9)

_____

Which therapeutic areas have benefited the most from innovative biotechnological advancements in personalized medicine? (Slide and rank these in order of impact)
_____ Oncology (e.g., personalised cancer treatments) (1)
_____ Neurology (e.g., tailored therapies for Alzheimer's or epilepsy) (2)
_____ Cardiovascular diseases (e.g., treatments based on genetic predispositions) (3)
_____ Infectious diseases (e.g., personalised vaccines or antibiotics) (4)
_____ Rare genetic disorders (e.g., cystic fibrosis) (5)
_____ Metabolic and Endocrine disorders (e.g., diabetes or obesity) (6)

Do you think that the higher cost of personalized medicine compared to traditional healthcare for patients is justified by the benefits it provides?

- ○ Definitely not (1)
- ○ Probably not (2)
- ○ Might or might not (3)
- ○ Probably yes (4)
- ○ Definitely yes (5)

End of Block: Biotechnological Contributions

Start of Block: Perceptions and future outlook

Do you believe personalized medicine will replace traditional healthcare "one-size-fits-all" approach in the future?

- ○ Definitely not (1)
- ○ Probably not (2)
- ○ Might or might not (3)
- ○ Probably yes (4)
- ○ Definitely yes (5)

How do you see the role of personalized medicine evolving in the future?

- ○ Transformative, it will dominate healthcare (1)
- ○ Incremental, it will coexist with traditional medicine (2)
- ○ Limited, its application will remain niche (3)

How long do you think it will take for personalized medicine to become a standard part of healthcare?

- ○ 2-5 years (1)
- ○ 5-10 years (2)
- ○ 10-20 years (3)
- ○ 20-30 years (4)
- ○ More than 30 years (5)
- ○ It won't happen (6)

End of Block: Perceptions and future outlook

Start of Block: Barriers, Strategies and Reflections

What do you think are the biggest barriers to implementing innovative biotechnology for personalized medicine? (select up to three)

- ☐ High costs of research and development (1)
- ☐ Strict regulations (2)
- ☐ Ethical concerns (e.g., genetic data privacy) (3)
- ☐ Difficulty scaling personalized treatments (4)
- ☐ Public skepticism or misinformation (5)
- ☐ Limited patient access to innovative treatments (6)
- ☐ Intense competition in the biotechnology industry (7)
- ☐ Difficulty attracting investors to fund new innovations (8)
- ☐ Other (please specify) (9)

_____

What strategies do you think could help overcome the barriers of personalized medicine therapies? (Select up to three)

- [ ] Increased government funding for biotechnology research and development (1)
- [ ] Leveraging AI and automation to optimize research and development (2)
- [ ] Enhance public education to reduce skepticism and misinformation (3)
- [ ] Improved collaboration between biotech companies and healthcare systems (4)
- [ ] Streamlining regulatory processes to accelerate approval timelines (5)
- [ ] Standardizing international regulations to facilitate global adoption (6)
- [ ] Other (please specify) (7)

_____

In your opinion, what is the most promising biotechnological innovation in personalized medicine, and why?(Please provide a brief explanation)

_____

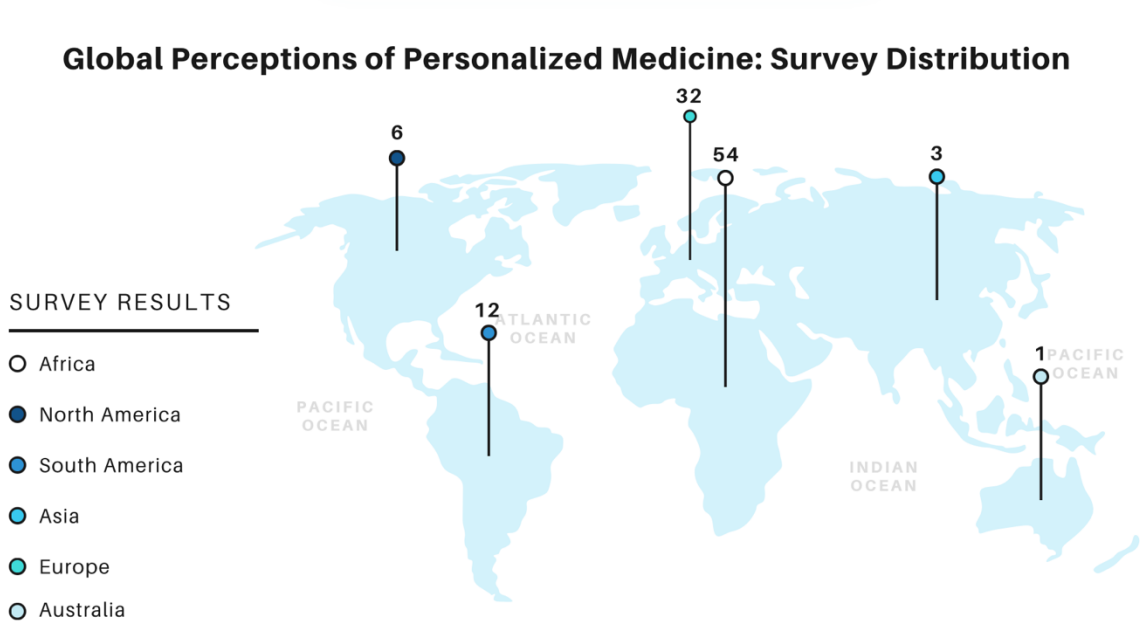
End of Block: Barriers, Strategies and Reflections

Appendix 15: Sample Characteristics

Table 1- Sample Characteristics

Distribution (n=108)					
Age			Education		
18-25	50	46%	Undergraduate	49	45%
26-35	46	43%	Master's	43	40%
36-50	9	8%	PhD	11	10%
50>	3	3%	Other	5	5%
Average	27,5				
Minimum	18		Familiarity Levels		
Maximum	65		Not Familiar	4	4%
St.dev	7,82		Slightly Familiar	15	14%
			Moderately Familiar	32	30%
Gender			Very Familiar	39	36%
Female	62	57%	Extremely Familiar	18	17%
Male	44	41%			
Other	2	2%			

Appendix 16: Survey Distribution Across Countries



Appendix 17: Crosstabulation Analysis of the Familiarity and Belief in Replacing Traditional Healthcare

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
FAMILIARITY(CODE) * BELIF IN PM REPLACING TRADITIONAL HEALTHCARE (CODE)	108	100.0%	0	0.0%	108	100.0%

FAMILIARITY(CODE) * BELIF IN PM REPLACING TRADITIONAL HEALTHCARE (CODE) Crosstabulation

			BELIF IN PM REPLACING TRADITIONAL HEALTHCARE (CODE)					
			Definitely not	Probably Not	Neutral	Probably Yes	Definitely Yes	Total
FAMILIARITY(CODE)	Unfamiliar	Count	1	6	4	7	1	19
		Expected Count	1.2	1.9	4.2	8.3	3.3	19.0
		% within FAMILIARITY (CODE)	5.3%	31.6%	21.1%	36.8%	5.3%	100.0%
	Knowledgeable	Count	1	2	7	17	5	32
		Expected Count	2.1	3.3	7.1	13.9	5.6	32.0
		% within FAMILIARITY (CODE)	3.1%	6.3%	21.9%	53.1%	15.6%	100.0%
	Familiar	Count	5	3	13	23	13	57
		Expected Count	3.7	5.8	12.7	24.8	10.0	57.0
		% within FAMILIARITY (CODE)	8.8%	5.3%	22.8%	40.4%	22.8%	100.0%
Total		Count	7	11	24	47	19	108
		Expected Count	7.0	11.0	24.0	47.0	19.0	108.0
		% within FAMILIARITY (CODE)	6.5%	10.2%	22.2%	43.5%	17.6%	100.0%

Appendix 18: Chi-Square Test of the Familiarity and Belief in Replacing Traditional Healthcare

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	15.061[a]	8	.058
Likelihood Ratio	12.960	8	.113
Linear-by-Linear Association	2.561	1	.110
N of Valid Cases	108		

a. 7 cells (46.7%) have expected count less than 5. The minimum expected count is 1.23.

Appendix 19: Crosstabulation Analysis of the Familiarity and Timeframe for PM Becoming Standard

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Regrouped Familiarity levels * Timeframe for PM Becoming Standard	108	100.0%	0	0.0%	108	100.0%

Regrouped Familiarity levels * Timeframe for PM Becoming Standard Crosstabulation

			Timeframe for PM Becoming Standard					
			2-5 years	5-10 year	10-20 years	20-30 years	More than 30 years	Total
Regrouped Familiarity levels	Unfamiliar	Count	0	4	8	4	3	19
		Expected Count	1.8	4.9	7.6	3.2	1.6	19.0
		% within Regrouped Familiarity levels	0.0%	21.1%	42.1%	21.1%	15.8%	100.0%
	Knowledgeable	Count	3	9	12	5	3	32
		Expected Count	3.0	8.3	12.7	5.3	2.7	32.0
		% within Regrouped Familiarity levels	9.4%	28.1%	37.5%	15.6%	9.4%	100.0%
	Familiar	Count	7	15	23	9	3	57
		Expected Count	5.3	14.8	22.7	9.5	4.8	57.0
		% within Regrouped Familiarity levels	12.3%	26.3%	40.4%	15.8%	5.3%	100.0%
Total		Count	10	28	43	18	9	108
		Expected Count	10.0	28.0	43.0	18.0	9.0	108.0
		% within Regrouped Familiarity levels	9.3%	25.9%	39.8%	16.7%	8.3%	100.0%

Appendix 20: Chi-Square Test of the Familiarity and Timeframe for PM Becoming Standard

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.851[a]	8	.773
Likelihood Ratio	6.383	8	.604
Linear-by-Linear Association	3.525	1	.060
N of Valid Cases	108		

a. 7 cells (46.7%) have expected count less than 5. The minimum expected count is 1.58.

Appendix 21: Crosstabulation Analysis of the Familiarity Levels and Role of PM

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Regrouped Familiarity levels * Role Of PM	108	100.0%	0	0.0%	108	100.0%

Regrouped Familiarity levels * Role Of PM Crosstabulation

			Role Of PM			
			Limited	Incremental	Transformative	Total
Regrouped Familiarity levels	Not Familiar	Count	4	12	3	19
		Expected Count	2.5	10.4	6.2	19.0
		% within Regrouped Familiarity levels	21.1%	63.2%	15.8%	100.0%
	Knowledgeable	Count	3	17	12	32
		Expected Count	4.1	17.5	10.4	32.0
		% within Regrouped Familiarity levels	9.4%	53.1%	37.5%	100.0%
	Familiar	Count	7	30	20	57
		Expected Count	7.4	31.1	18.5	57.0
		% within Regrouped Familiarity levels	12.3%	52.6%	35.1%	100.0%
Total		Count	14	59	35	108
		Expected Count	14.0	59.0	35.0	108.0
		% within Regrouped Familiarity levels	13.0%	54.6%	32.4%	100.0%

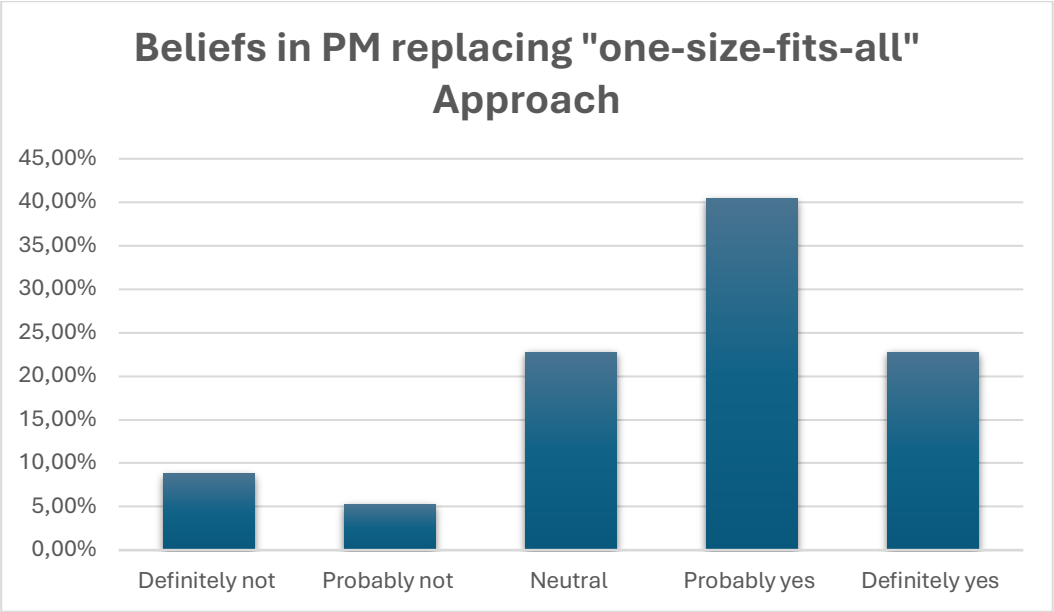
Appendix 22: Chi-Square Test of the Familiarity Levels and Role of PM

Chi-Square Tests

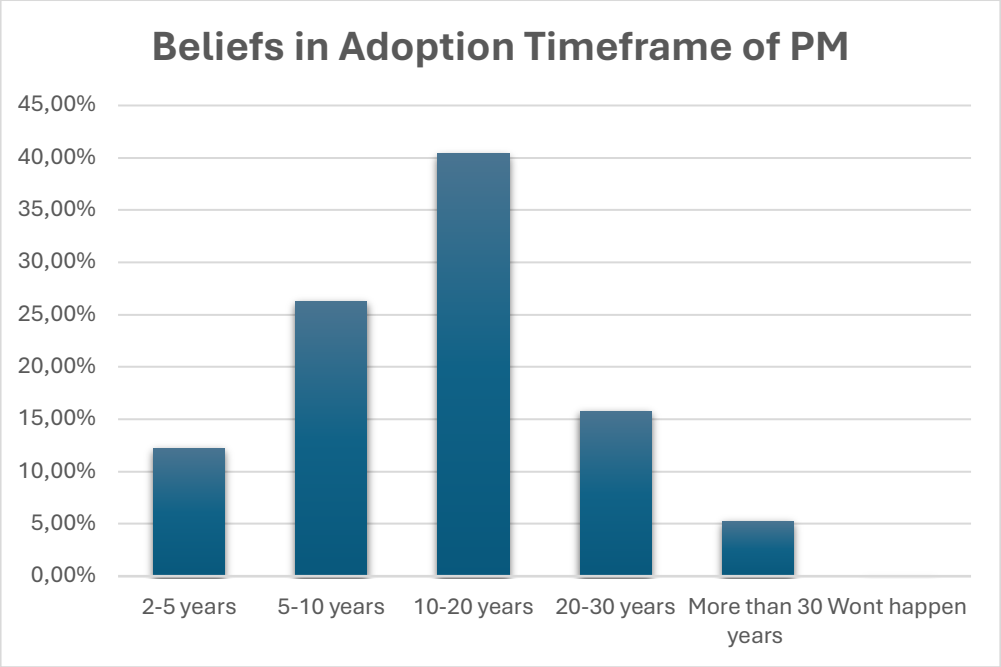
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.607[a]	4	.462
Likelihood Ratio	3.842	4	.428
Linear-by-Linear Association	1.662	1	.197
N of Valid Cases	108		

a. 2 cells (22.2%) have expected count less than 5. The minimum expected count is 2.46.

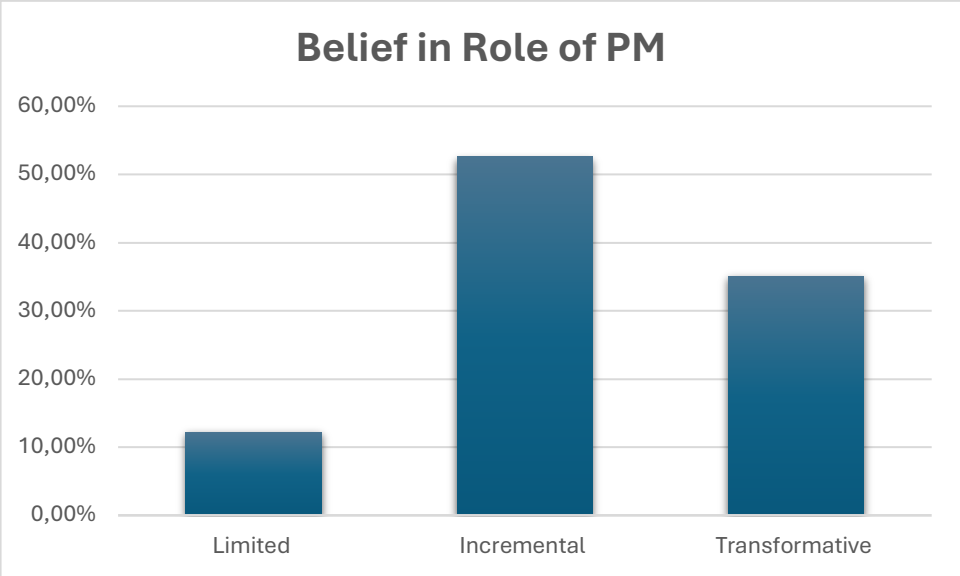
Appendix 23: Clustered Column in Belief in PM Replacing "one-size-fits-all" Approach



Appendix 24: Clustered Column on perceived Adoption Timeframe of PM



Appendix 25: Clustered Column on beliefs in the role of PM



Appendix 26: Definitions of the different Contributions

Biotechnologies	Definition
CAR-T	an innovative treatment for the management of blood cancers
CRISPR	The CRISPR system can correct or modify the expression of genes responsible for hereditary diseases
NGS	High-throughput sequencing or next-generation sequencing (NGS) is a molecular methodology that allows the rapid sequencing of thousands to millions of DNA or RNA molecules simultaneously, by determining the unique and specific order of acid bases. nucleic acids. This tool therefore allows the sequencing of several genes and several individuals simultaneously, by comparing the patient's sequence to a reference sequence.
3D bioprinting	Three-dimensional (3D) bioprinting technology is a cutting-edge solution that involves layer-by-layer deposition of biological materials, including various cell types, bioinks, and growth factors, to create 3D structures that mimic architecture. and the functioning of 3D cellular models
wearable devices	Wearable technology in healthcare refers to devices that patients attach to their bodies to collect health and fitness data

AI for drug discovery	The use of AI in drug discovery entails generating new content such as molecules, compounds, or drug candidates based on specific criteria sets
molecular diagnosis	Molecular diagnostics is a collection of techniques used to analyze biological markers in the genome and proteome, and how their cells express their genes as proteins
Biobanks	Biobanks are storage facilities that house blood samples, DNA, tissue samples and tumour cells that are used for research purposes.

Appendix 27: Crosstabulation Analysis of Familiarity Level and Contributions to PM

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Familiarity Level * Contribution	353	100.0%	0	0.0%	353	100.0%

Familiarity Level * Contribution Crosstabulation

			Contribution								
			3D Bioprinting	AI in Drug Discovery	BioBanks	CAR-T	CRISPR	Molecular Diagnosis	NGS	Wearable devices	Total
Familiarity Level	Unfamiliar	Count	4	3	3	7	13	11	13	4	58
		Expected Count	3.0	3.0	5.8	8.2	10.0	10.4	13.1	4.6	58.0
		% within Familiarity Level	6.9%	5.2%	5.2%	12.1%	22.4%	19.0%	22.4%	6.9%	100.0%
	Knowledgeable	Count	5	5	12	17	20	22	29	9	119
		Expected Count	6.1	6.1	11.8	16.9	20.6	21.2	27.0	9.4	119.0
		% within Familiarity Level	4.2%	4.2%	10.1%	14.3%	16.8%	18.5%	24.4%	7.6%	100.0%
	Familiar	Count	9	10	20	26	28	30	38	15	176
		Expected Count	9.0	9.0	17.5	24.9	30.4	31.4	39.9	14.0	176.0
		% within Familiarity Level	5.1%	5.7%	11.4%	14.8%	15.9%	17.0%	21.6%	8.5%	100.0%
Total		Count	18	18	35	50	61	63	80	28	353
		Expected Count	18.0	18.0	35.0	50.0	61.0	63.0	80.0	28.0	353.0
		% within Familiarity Level	5.1%	5.1%	9.9%	14.2%	17.3%	17.8%	22.7%	7.9%	100.0%

Appendix 28: Chi-Square test of Familiarity Level and Contributions to PM

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.423[a]	14	.992
Likelihood Ratio	4.608	14	.991
N of Valid Cases	353		

a. 3 cells (12.5%) have expected count less than 5. The minimum expected count is 2.96.

Appendix 29: Crosstabulation Analysis of Familiarity Levels and Perceived Therapeutic Areas that have Benefited the Most from PM

Area * Rank * Familiarity Crosstabulation

Familiarity				Rank						
				1	2	3	4	5	6	Total
Familiar	Area	Cardiovascular diseases	Count	9	11	10	7	13	7	57
			Expected Count	9.5	9.5	9.5	9.5	9.5	9.5	57.0
			% within Area	15.8%	19.3%	17.5%	12.3%	22.8%	12.3%	100.0%
		Infectious diseases	Count	7	20	11	7	6	6	57
			Expected Count	9.5	9.5	9.5	9.5	9.5	9.5	57.0
			% within Area	12.3%	35.1%	19.3%	12.3%	10.5%	10.5%	100.0%
		Metabolic and Endorcine disorders	Count	4	6	5	15	16	11	57
			Expected Count	9.5	9.5	9.5	9.5	9.5	9.5	57.0
			% within Area	7.0%	10.5%	8.8%	26.3%	28.1%	19.3%	100.0%
		Neurology	Count	6	11	7	6	11	16	57
			Expected Count	9.5	9.5	9.5	9.5	9.5	9.5	57.0
			% within Area	10.5%	19.3%	12.3%	10.5%	19.3%	28.1%	100.0%
		Oncology	Count	28	3	5	15	3	3	57
			Expected Count	9.5	9.5	9.5	9.5	9.5	9.5	57.0
			% within Area	49.1%	5.3%	8.8%	26.3%	5.3%	5.3%	100.0%
		Rare genetic disorders	Count	3	6	19	7	8	14	57
			Expected Count	9.5	9.5	9.5	9.5	9.5	9.5	57.0
			% within Area	5.3%	10.5%	33.3%	12.3%	14.0%	24.6%	100.0%
	Total		Count	57	57	57	57	57	57	342
			Expected Count	57.0	57.0	57.0	57.0	57.0	57.0	342.0
			% within Area	16.7%	16.7%	16.7%	16.7%	16.7%	16.7%	100.0%
Knowledeagble	Area	Cardiovascular diseases	Count	5	9	7	6	2	3	32
			Expected Count	5.3	5.3	5.3	5.3	5.3	5.3	32.0
			% within Area	15.6%	28.1%	21.9%	18.8%	6.3%	9.4%	100.0%
		Infectious diseases	Count	1	9	7	3	4	8	32
			Expected Count	5.3	5.3	5.3	5.3	5.3	5.3	32.0
			% within Area	3.1%	28.1%	21.9%	9.4%	12.5%	25.0%	100.0%
		Metabolic and Endorcine disorders	Count	3	4	3	5	7	10	32
			Expected Count	5.3	5.3	5.3	5.3	5.3	5.3	32.0
			% within Area	9.4%	12.5%	9.4%	15.6%	21.9%	31.3%	100.0%
		Neurology	Count	5	7	8	4	6	2	32
			Expected Count	5.3	5.3	5.3	5.3	5.3	5.3	32.0
			% within Area	15.6%	21.9%	25.0%	12.5%	18.8%	6.3%	100.0%
		Oncology	Count	15	1	3	8	3	2	32
			Expected Count	5.3	5.3	5.3	5.3	5.3	5.3	32.0
			% within Area	46.9%	3.1%	9.4%	25.0%	9.4%	6.3%	100.0%
		Rare genetic disorders	Count	3	2	4	6	10	7	32
			Expected Count	5.3	5.3	5.3	5.3	5.3	5.3	32.0
			% within Area	9.4%	6.3%	12.5%	18.8%	31.3%	21.9%	100.0%
	Total		Count	32	32	32	32	32	32	192
			Expected Count	32.0	32.0	32.0	32.0	32.0	32.0	192.0
			% within Area	16.7%	16.7%	16.7%	16.7%	16.7%	16.7%	100.0%
Unfamiliar	Area	Cardiovascular diseases	Count	5	1	6	2	4	1	19
			Expected Count	3.2	3.2	3.2	3.2	3.2	3.2	19.0
			% within Area	26.3%	5.3%	31.6%	10.5%	21.1%	5.3%	100.0%
		Infectious diseases	Count	0	5	3	5	3	3	19
			Expected Count	3.2	3.2	3.2	3.2	3.2	3.2	19.0
			% within Area	0.0%	26.3%	15.8%	26.3%	15.8%	15.8%	100.0%
		Metabolic and Endorcine disorders	Count	0	2	2	4	5	6	19
			Expected Count	3.2	3.2	3.2	3.2	3.2	3.2	19.0
			% within Area	0.0%	10.5%	10.5%	21.1%	26.3%	31.6%	100.0%
		Neurology	Count	7	3	3	1	2	3	19
			Expected Count	3.2	3.2	3.2	3.2	3.2	3.2	19.0
			% within Area	36.8%	15.8%	15.8%	5.3%	10.5%	15.8%	100.0%
		Oncology	Count	7	6	0	4	1	1	19
			Expected Count	3.2	3.2	3.2	3.2	3.2	3.2	19.0
			% within Area	36.8%	31.6%	0.0%	21.1%	5.3%	5.3%	100.0%
		Rare genetic disorders	Count	0	2	5	3	4	5	19
			Expected Count	3.2	3.2	3.2	3.2	3.2	3.2	19.0
			% within Area	0.0%	10.5%	26.3%	15.8%	21.1%	26.3%	100.0%
	Total		Count	19	19	19	19	19	19	114
			Expected Count	19.0	19.0	19.0	19.0	19.0	19.0	114.0
			% within Area	16.7%	16.7%	16.7%	16.7%	16.7%	16.7%	100.0%
Total	Area	Cardiovascular diseases	Count	19	21	23	15	19	11	108
			Expected Count	18.0	18.0	18.0	18.0	18.0	18.0	108.0
			% within Area	17.6%	19.4%	21.3%	13.9%	17.6%	10.2%	100.0%
		Infectious diseases	Count	8	34	21	15	13	17	108
			Expected Count	18.0	18.0	18.0	18.0	18.0	18.0	108.0
			% within Area	7.4%	31.5%	19.4%	13.9%	12.0%	15.7%	100.0%
		Metabolic and Endorcine disorders	Count	7	12	10	24	28	27	108
			Expected Count	18.0	18.0	18.0	18.0	18.0	18.0	108.0
			% within Area	6.5%	11.1%	9.3%	22.2%	25.9%	25.0%	100.0%
		Neurology	Count	18	21	18	11	19	21	108
			Expected Count	18.0	18.0	18.0	18.0	18.0	18.0	108.0
			% within Area	16.7%	19.4%	16.7%	10.2%	17.6%	19.4%	100.0%
		Oncology	Count	50	10	8	27	7	6	108
			Expected Count	18.0	18.0	18.0	18.0	18.0	18.0	108.0
			% within Area	46.3%	9.3%	7.4%	25.0%	6.5%	5.6%	100.0%
		Rare genetic disorders	Count	6	10	28	16	22	26	108
			Expected Count	18.0	18.0	18.0	18.0	18.0	18.0	108.0
			% within Area	5.6%	9.3%	25.9%	14.8%	20.4%	24.1%	100.0%
	Total		Count	108	108	108	108	108	108	648
			Expected Count	108.0	108.0	108.0	108.0	108.0	108.0	648.0
			% within Area	16.7%	16.7%	16.7%	16.7%	16.7%	16.7%	100.0%

Appendix 30: Chi-Square test of Familiarity Levels and Perceived Therapeutic Areas that have Benefited the Most from PM

Chi-Square Tests

Familiarity		Value	df	Asymptotic Significance (2-sided)
Familiar	Pearson Chi-Square	114.211[b]	25	<.001
	Likelihood Ratio	103.699	25	<.001
	N of Valid Cases	342		
Moderatly	Pearson Chi-Square	61.500[c]	25	<.001
	Likelihood Ratio	60.045	25	<.001
	N of Valid Cases	192		
Unfamiliar	Pearson Chi-Square	46.421[d]	25	.006
	Likelihood Ratio	57.110	25	<.001
	N of Valid Cases	114		
Total	Pearson Chi-Square	162.556[a]	25	<.001
	Likelihood Ratio	153.243	25	<.001
	N of Valid Cases	648		

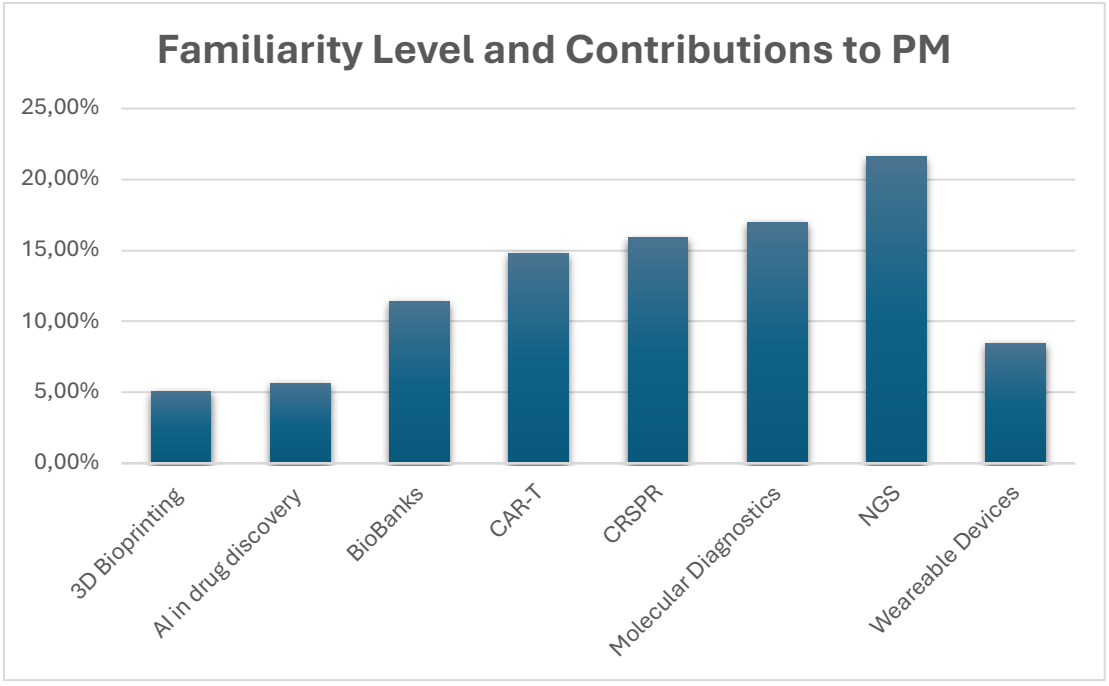
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 18.00.

b. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.50.

c. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.33.

d. 36 cells (100.0%) have expected count less than 5. The minimum expected count is 3.17.

Appendix 31: Clustered Column on the belief of Major Contribution of Biotech to PM



Appendix 32: Open-ended Question Results

Table 2- Open-ended question regarding the most promising biotechnology innovation in PM

Distribution (n= 56)	
'Extremely Familiar'	
NGS	*"Advances in the **next generation**, by understanding genetic variations health care providers can prescribe more effective medicine."*
CRISPR-cas9	***"CRISPR-Cas9** because of its ability to precisely edit genes, offering potential cures for genetic diseases and advancing treatments across multiple fields like cancer and rare disorders."*
	*"**CRISPR-Cas9** is transformative because of its ability to precisely edit genes, offering unprecedented opportunities for treating genetic disorders at their root cause."*
	*"One of the most promising biotechnological innovations in personalized medicine is **CRISPR-Cas9** gene editing technology. This tool allows precise editing of DNA, enabling targeted correction of genetic mutations that cause diseases such as sickle cell anemia or certain cancers. Its potential to tailor treatments to individual genetic profiles makes it revolutionary. CRISPR's versatility, efficiency, and cost-effectiveness position it as a game-changer in developing highly personalized and curative therapies."*
	*"**CRISPR-based gene editing**, due to its broad applicability, more importantly in the developing world context, can allow researchers to target viruses like HIV and permanently eliminate it from the body. Additionally, there is ongoing research to minimize costs and accessibility."*
	*"**CRISPR gene editing** is a groundbreaking biotechnological innovation in personalized medicine. It enables precise editing of specific genes responsible for genetic diseases, allowing for tailored treatments based on individual genetic profiles. With potential applications in treating sickle cell anemia, cystic fibrosis, muscular dystrophy, and cancer, CRISPR offers a promising avenue for effective treatments and possible cures. Its precision reduces side effects, paving the way for preventive medicine and personalized healthcare advancements. As research evolves, CRISPR's transformative impact on medicine will continue to grow."*

	"**CRISPR** because it is pertinent to a huge number of areas when it comes to both investigating and treating diseases."
Molecular Diagnosis	*"I believe that **molecular diagnosis** is the most promising one because it's aiming at the actual function or dysfunction of the particular molecule or mechanism or pathway."*
CAR-T	*"**CAR-T CELLS** because we can heal a lot of difficult diseases with this innovation."*
Gene Editing	*"**Gene editing** because it potentially addresses previously untreatable diseases and etiologies of a plethora of diseases with predominantly genetic etiology."*
	*"The use of **gene editing** to minimize diseases that have a genetic component and are comorbid with other diseases, such as obesity. This will reduce the cost of healthcare systems internationally overall."*
AI	*"Using **AI** and quantum processing to speed up drug discovery, to reduce the time to produce a new drug."*
	*"Personalized medicine is revolutionizing healthcare, and one of the most promising biotechnologies in this field is **gene editing**. This technology enables faster, more affordable genetic testing, allowing doctors to tailor treatments to individual payments based on their unique genetic profiles."*
Biomarkers	*"**Biomarkers** for treatments of cancer and crisp cas9 gene editing"*
GWAS	*"**GWAS** represents an incredible innovation in personalized medicine because it uncovers genetic variants associated with complex traits and diseases, enabling targeted interventions and enabling better healthcare solutions."*
Immunotherapy	*"**immunotherapy**"*
Pills	*"I think the ability to create a **pill that combines all the drugs that a person should be taking**. It should be created in such a way that it doesn't counter-react with the other active substances."*

‘Very Familiar’

NGS

“*One of the most promising innovations in personalized medicine is the use of* ***next-generation sequencing (NGS****). This technology allows for rapid and cost-effective sequencing of an individual's genome, enabling healthcare providers to identify genetic predispositions to diseases and tailor treatments accordingly. By understanding a patient's unique genetic makeup, NGS facilitates targeted therapies, optimizing drug efficacy and minimizing adverse effects, thus significantly enhancing the precision of medical care.”*

CRISPR-cas9

“*I think the most promising biotechnological innovation is* ***CRISPR*** *Gen Editing because it has the potential for cure; CRISPR offers the possibility of curing genetic diseases rather than just managing symptoms.*

“Gene editing using ***CRISPR-Cas9*** *technology because it is being used to treat genetic illnesses like sickle cell anemia.”*

“Gene editing technologies, particularly ***CRISPR/Cas9****, hold great promise in personalized medicine. This innovation enables precise modifications to an individual's genome, allowing for tailored treatments for genetic diseases. Its potential to revolutionize the field lies in its: - Precision: Targeted editing of specific genes - Efficiency: High success rates in modifying genes - Flexibility: Applicable to various cell types and diseases. This technology has the potential to transform the treatment of genetic disorders, offering hope for patients with previously incurable diseases.”*

“Precision and Flexibility: ***CRISPR*** *allows for highly targeted modifications to DNA, enabling the correction of genetic mutations that cause diseases at their root cause. This precision opens doors to treating genetic disorders such as sickle cell anemia, cystic fibrosis, and potentially more complex conditions like muscular dystrophy. 2. Personalized Treatment: CRISPR can be used to edit a patient’s own cells, offering personalized therapies that are tailored to the specific genetic abnormalities of the individual. This creates the potential for one-time cures that eliminate the need for lifelong treatments. 3. Expanding Beyond Genetic Diseases: While gene editing started with rare genetic disorders, CRISPR is rapidly being explored for applications in cancer treatment, where it could be used to modify immune cells to better target and fight cancer cells. This adaptability makes CRISPR a cornerstone for personalized medicine in the future.”*

“The use of ***CRISPR techniques*** *to combat genetic diseases.”*

*"The most promising biotechnological innovation in personalized medicine is **CRISPR-Cas9** gene editing. It offers precise and cost-effective solutions for treating genetic disorders, improving immunotherapies, and advancing drug delivery systems, making it a transformative tool for personalized healthcare."*

*"One of the most promising biotechnological innovations in personalized medicine is **definitely CRISPR-Cas9** gene editing. This technology allows for precise and targeted modifications of the genome, enabling corrections of genetic mutations that cause diseases that alter the genetic makeup. Its efficiency, adaptability, and decreasing cost make it revolutionary for tailoring treatments to an individual's genetic profile. CRISPR can be combined with other technologies, like mRNA therapies, to make personalized patient therapeutic treatments."*

*"Genetic disease prevention - **CRISPR** can edit genes to prevent inherited diseases."*

*"It is **CRISPR** because it will deliver methods and specificity. And it will also have the potential to treat previously incurable diseases."*

*"One of the most promising biotechnological innovations in personalized medicine is the development and application of **CRISPR-Cas9** gene-editing technology. This tool allows precise modifications to DNA, enabling the correction of genetic mutations that underlie many diseases, as well as the potential to tailor treatments to an individual's unique genetic profile."*

*"**CRISPR** Gene Editing reason being it is more efficient than your traditional gene therapy methods and for itself flexibility as it can be used for various applications."*

*"**CRISPR**: gene/DNA editing which is cost-effective and efficient and can treat many genetic disorders and mutations."*

*"It is the Clusters Regularly Interspaces Short Palindromic Repeats. **CRISPR-Cas9**, because of its versatility, potential for curative therapies, and widespread application in personalized medicine."*

Gene Editing

*"**Gene editing** this is because the tool allows scientists to make changes to the DNA of living cells in order to correct genetic mutations that cause disease."*

*"**Gene editing**, genomics and molecular profiling, personalized oncology treatments, and wearable and digital health devices."*

	*"**Gene editing** because it allows for the "curing" of lifelong diseases and increases life expectancy."*
	*"The ones that involve **genetics.**"*
	*"I believe the **gene-editing** technology which allows for specific genome mutation in diseases like cancer."*
	*"Not sure, but I think **alterations of gene mutations** to give optimum results, thus will reduce the occurrence of disease as the genes which are not desirable are eliminated."*
Cell Cycle Repair	*"**Cell cycle repair** technologies as they directly address the mechanism underlying cell division, DNA repair, and cellular homeostasis and address disease at the molecular level, targeting specific pathways unique to the individual and providing solutions that are customizable and efficient. It will enable to repair the very foundation of cellular health and be a transformative technology for PM."*
AI	*"**AI** medical imaging diagnostics, annotation, and labeling will spearhead patients treatment and reduce hospital stay and mortality rates."*
	*"Is the integration of **artificial intelligence. AI** with genomics and proteomics, this combination has the potential to revolutionize healthcare by enabling the development of highly personalized treatment plans based on a patient's unique genetic and molecular profile."*
	*"I think the most promising biotechnological innovation in personalized medicine would be the use of **AI-powered tools**. It can process data a lot faster and precise than human beings, for instance when doing a whole exome sequencing for a patient with a rare disease."*
	*"**Wearable devices**, they are powered by the fast-**evolving artificial intelligence** and are most accessible"*
Genomic Sequencing	*"**Genomic sequencing**, I think it's one technology that allows us to sequence an individual entire genome, which I think can reveal some genetics variations that may increase their risk of certain diseases or even affect how they respond to medication."*

	*"I think the most promising biotechnological innovation in personalized medicine now has to be **genomics**. I think because this field has been rapidly advancing and there is significant progress understanding the genetic factors that contribute to complex disease."*
Biomarkers	*"I think it's personalized medicine, particularly in the development and implementation of tests for **biomarkers**."*
	*"The most promising biotechnological innovation is Point of care treatment, using biosensors to easily find traces of cancer **biomarkers** for example."*
CAR-T	*"**CAR-T**, because I love how we can use and modify our T cells to direct them into the target we want."*
Oncology Innovations	*"Single cell oncotherapy to prevent **cancer** spread and metastasis"*
	*"New **cancer treatments**"*
	*"The most promising biotechnological innovation is in **oncology**. This is because, at this time, there are no therapies to prevent it."*
Molecular Diagnosis	*"**Molecular diagnostics** to scan for diseases."*
Brain Organoid	*"**Brain organoid research** is currently my favorite innovation as it borders the ethics vs medicinal value arguments very well. It is both a medical and moral dilemma to be able to take pieces of a brain, cultivate it, and then use it to either have functionality on its own or even to be used to repair brain damage in patients. The question begs for answers about sentience, morality, the soul/religion, medicine, as well as scientific limitations."*
mRNA	*"Drugs in nanoparticles with **mRNA**"*
	*"**RNA therapeutics** has shown huge success in animals with heart failure, and it can improve the treatment of other conditions as well."*
Diabetes Innovation	*"**Diabetes medicine**. Because it is a silent killer."*
Pharmaco-	*"**Pharmacogenomics**: knowing why "one size fits all" regular*

Genomics *medications do not work properly in some individuals by analyzing genes and SNPs."*

Appendix 33: Crosstabulation on Familiarity Levels and Perceived Barriers to PM's Implementation

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Familiarity Levels * Barriers	341	100.0%	0	0.0%	341	100.0%

Familiarity Levels * Barriers Crosstabulation

			Barriers								
			Difficulty attracting investors to fund new innovations	Difficulty scaling personalized treatments	Ethical concerns (e.g., genetic data privacy)	High costs of research and development	Intense competition in the biotechnology industry	Limited patient access to innovative treatments	Public skepticism or misinformation	Strict regulations	Total
Familiarity Levels	Familiar	Count	21	15	29	52	8	28	15	16	184
		Expected Count	18.3	17.3	27.0	51.8	9.2	26.4	19.4	14.6	184.0
		% within Familiarity Levels	11.4%	8.2%	15.8%	28.3%	4.3%	15.2%	8.2%	8.7%	100.0%
	Knowledgeable	Count	7	13	10	26	4	16	17	6	99
		Expected Count	9.9	9.3	14.5	27.9	4.9	14.2	10.5	7.8	99.0
		% within Familiarity Levels	7.1%	13.1%	10.1%	26.3%	4.0%	16.2%	17.2%	6.1%	100.0%
	Unfamiliar	Count	6	4	11	18	5	5	4	5	58
		Expected Count	5.8	5.4	8.5	16.3	2.9	8.3	6.1	4.6	58.0
		% within Familiarity Levels	10.3%	6.9%	19.0%	31.0%	8.6%	8.6%	6.9%	8.6%	100.0%
Total		Count	34	32	50	96	17	49	36	27	341
		Expected Count	34.0	32.0	50.0	96.0	17.0	49.0	36.0	27.0	341.0
		% within Familiarity Levels	10.0%	9.4%	14.7%	28.2%	5.0%	14.4%	10.6%	7.9%	100.0%

Appendix 34: Chi-Square Test on Familiarity Levels and Perceived Barriers to PM's Implementation

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	15.942[a]	14	.317
Likelihood Ratio	15.532	14	.343
N of Valid Cases	341		

a. 3 cells (12.5%) have expected count less than 5. The minimum expected count is 2.89.

Appendix 35: Crosstabulation on Familiarity Levels and Strategies

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Familiarity * Strategies	325	100.0%	0	0.0%	325	100.0%

Familiarity * Strategies Crosstabulation

			Strategies						
			Enhance public education to reduce skepticism and misinformation	Improved collaboration between biotech companies and healthcare systems	Increased government funding for biotechnology research and development	Leveraging AI and automation to optimize research and development	Standardizing international regulations to facilitate global adoption	Streamlining regulatory processes to accelerate approval timelines	Total
Familiarity	Familiar	Count	22	37	50	19	24	17	169
		Expected Count	22.4	39.0	47.8	18.2	24.4	17.2	169.0
		% within Familiarity	13.0%	21.9%	29.6%	11.2%	14.2%	10.1%	100.0%
	Knowledgeable	Count	12	24	27	11	16	11	101
		Expected Count	13.4	23.3	28.6	10.9	14.6	10.3	101.0
		% within Familiarity	11.9%	23.8%	26.7%	10.9%	15.8%	10.9%	100.0%
	Unfamiliar	Count	9	14	15	5	7	5	55
		Expected Count	7.3	12.7	15.6	5.9	8.0	5.6	55.0
		% within Familiarity	16.4%	25.5%	27.3%	9.1%	12.7%	9.1%	100.0%
Total		Count	43	75	92	35	47	33	325
		Expected Count	43.0	75.0	92.0	35.0	47.0	33.0	325.0
		% within Familiarity	13.2%	23.1%	28.3%	10.8%	14.5%	10.2%	100.0%

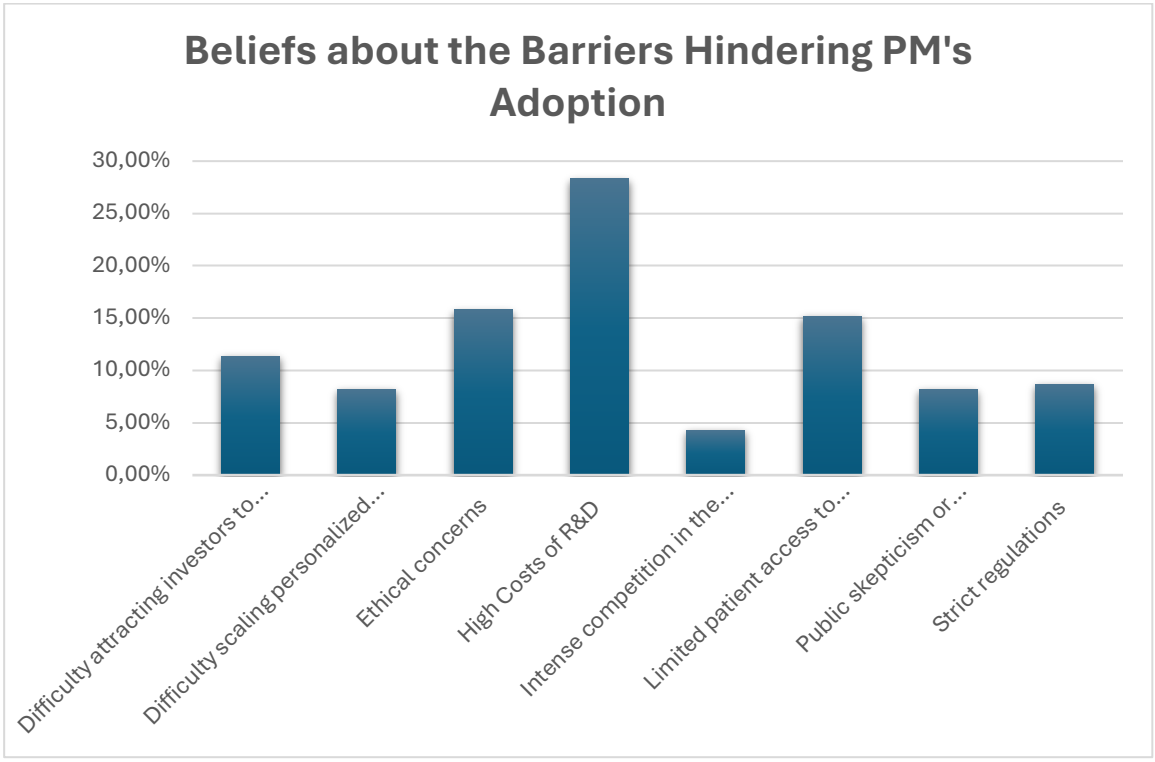
Appendix 36: Chi-Square test on Familiarity Levels and Strategies

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.570[a]	10	.999
Likelihood Ratio	1.553	10	.999
N of Valid Cases	325		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.58.

Appendix 37: Clustered Column regarding Barriers to PM's Implementation



Appendix 38: Clustered Colum regarding Strategies to Successful Implementation of PM