
MJ MULTISCIA
JOURNALS PUBLISHERS
FRONTIERS IN PHARMACOLOGICAL RESEARCH
ISSN: (3065- 1379)
https://multisciajournals.com/journals/index.php/fpr
editor.fpr@gmail.com

Frontiers in Pharmacological Research
Volume 2 Issue 1 2026

Precision medicine's future: incorporating genetic engineering with pharmacological studies One

Michael, Wan Chan ,Chuan Chou

Department of **Pharmacological Research**

Article Info

Received: 15-12-2025 Revised:19-1-2026 Accepted:21-2-2026 Published:23-3-2026

Keywords: Drug discovery Gene treatments

Precision medicine is changing as a result of the incorporation of genetic engineering into pharmacological research, which has the potential to completely reshape healthcare. Beyond the conventional "one-size-fits-all" approach, precision medicine focuses on customizing treatments for each patient based on genetic, environmental, and lifestyle factors. This editorial explores the uses of genetic engineering in drug discovery, pharmacogenomics, and novel therapeutics like gene and cell treatments, highlighting the critical role that genetic engineering plays in advancing precision medicine. Advances in omics technology and tools like CRISPR-Cas9 have improved our understanding of disease pathways and expedited the development of tailored medicines. Even with these advances, problems still exist. It is necessary to solve technical obstacles such off-target effects, ethical issues with germline editing, and the high expense of these technologies. However, there are many opportunities, from collaborative research projects that promise to expedite the development of genetic engineering applications to advances powered by artificial intelligence. In addition to changing medication development, this convergence of disciplines is broadening the therapeutic toolkit to address complicated illnesses. The promise of precision medicine—treatments customized to each person's genetic blueprint—is quickly coming to pass with consistent funding, interdisciplinary cooperation, and a focus on fair access.

With the potential to customize therapies for each patient based on their genetic, environmental, and lifestyle characteristics, precision medicine has completely changed the healthcare industry (Marques et al., 2024). The merging of genetic engineering and pharmacological research, which has the potential to transform medication development, improve therapeutic efficacy, and reduce side effects, is at the core of this revolution (Alzoubi et al., 2023). This editorial summarizes significant developments, looks at the opportunities and challenges that lie ahead in the quest for precision medicine, and investigates the dynamic interaction between genetic engineering and pharmacology. Traditional medicine has long used a "one-size-fits-all" strategy, developing and prescribing therapies under the presumption that they will be effective for everyone. However, this model's weaknesses have been exposed by individual heterogeneity in drug responses, which are caused by genetic variances (Jamrat et al., 2023; Sugandh et al., 2023). By using patient-specific data to inform clinical judgments, precision medicine aims to get around these restrictions. This paradigm change is greatly aided by genetic engineering, which offers the means to modify and comprehend the genetic foundations of illness and treatment response (Strianese et al., 2020; Puccetti et al., 2024).

A variety of technologies are included in genetic engineering, which makes it possible to precisely alter DNA sequences. Our capacity to modify genomes with previously unheard-of precision has been transformed by methods like CRISPR-Cas9, TALENs, and zinc-finger nucleases. These instruments are currently being used in a number of pharmacological research areas, such as drug development, discovery, and customized treatment plans (Hsu et al., 2014; Aljabali et al., 2024; Dutta, 2024a, 2024b). Because genetic engineering makes it possible to create more precise disease models, medication discovery has increased. For example, CRISPR technology enables researchers to imitate the genetic causes of human diseases by introducing particular mutations into cell lines or animal models. These models are crucial for identifying possible therapeutic candidates and comprehending molecular disease pathways (Rubbini et al., 2020; Wang and Doudna, 2023). Genetic engineering also makes it easier to produce biologics, such as gene treatments, recombinant proteins, and monoclonal antibodies. These biologics are increasingly serving as the mainstay of therapies for illnesses like genetic disorders, autoimmune diseases, and cancer. These compounds can be fine-tuned by genetic engineering to improve their safety, efficacy, and specificity (Banerjee and Ward, 2022; Szkodny and Lee, 2022).

Precision medicine relies heavily on pharmacogenomics, the study of how genes affect drug responses. A drug's metabolism, effectiveness, and toxicity can all be greatly impacted by genetic differences in enzymes, receptors, and transporters. Researchers can find and confirm these differences by using genetic engineering, opening the door to customized treatments (Ahmed et al., 2016; Qahwaji et al., 2024). For instance, individual disparities in drug clearance rates may result from polymorphisms in the CYP450 family of enzymes, which metabolize numerous pharmaceuticals. The functional impact of these polymorphisms can be studied by using genetic engineering techniques to develop animal or cell models that house them.

and guiding clinical practice dose modifications (Hossam et al., 2024).

Some of the most obvious uses of genetic engineering in precision medicine are gene and cell treatments. In order to treat or prevent disease, these therapies entail the insertion, removal, or modification of genetic material. For example, several forms of leukemia and lymphoma have been remarkably successfully treated with CAR-T cell therapy, which alters a patient's T cells to target cancer cells (Bulcha et al., 2021; Yu et al., 2022). In a similar vein, gene-editing techniques are being investigated to address genetic flaws that underlie monogenic diseases such Duchenne muscular dystrophy, sickle cell anemia, and cystic fibrosis. These treatments demonstrate how genetic engineering can heal diseases that were previously incurable and show how it has revolutionized pharmacology (Deneault, 2024).

Although the incorporation of genetic engineering into pharmaceutical

Although research has great potential, it is not without difficulties. For precision medicine to reach its full potential, these obstacles must be overcome. It is still very difficult to achieve accurate and effective gene editing. When unwanted parts of the genome are altered, this is known as an off-target effect, and it can have unfavorable consequences and raise safety issues. To get over this restriction, improvements in bioinformatics and the development of more precise editing tools are essential. Furthermore, creating effective treatments is difficult due to the intricacy of polygenic disorders, which are caused by the interaction of several genes and environmental variables. Large-scale genomic datasets and complex computer models are needed to comprehend these complex connections (Aljabali et al., 2024; Merlin and Abrahamse, 2024). Ethical concerns are raised by the use of genetic engineering, especially with regard to germline editing, which entails changes that may be handed down to future generations. Gaining the public's trust and guaranteeing fair access to these technologies depend on striking a balance between scientific advancement and ethical responsibility. Gene-edited product regulations are continually developing. To make it easier to translate advances in genetic engineering into clinical practice, precise recommendations addressing safety, efficacy, and quality control must be developed (Rubeis and Steger, 2018; Almeida and Ranisch, 2022). Access to genetic engineering methods and treatments is restricted due to their high cost, especially in low- and middle-income nations. To guarantee that the advantages of precision medicine are distributed fairly throughout the world, efforts to lower costs through innovation, scale-up, and public-private partnerships are required (Doxzen et al., 2024).

Despite these difficulties, there are many chances for innovation and effect when genetic engineering is used into pharmaceutical research. Precision medicine can benefit from the abundance of data provided by the development of omics technologies, such as proteomics, transcriptomics, and genomes. A deeper comprehension of disease biology and treatment response is made possible by integrating these datasets with genetic engineering methods, which propels the creation of targeted therapeutics (Chakraborty et al., 2024; Mohr et al., 2024). By making it possible to analyze complicated genetic datasets, artificial intelligence (AI) and machine learning (ML) are transforming pharmaceutical research. These technologies speed up the process from discovery to application by predicting off-target effects, identifying druggable targets, and optimizing the design of gene-editing tools (Quazi, 2022; Yadav et al., 2024). To advance genetic engineering in pharmacology, cooperation between government, business, and academia is crucial. Projects like the All of Us Research Program and the Human Genome Project show how teamwork may provide important genetic insights and promote creativity (Heilbron et al., 2021). From RNA-based treatments and CRISPR-based gene editing to synthetic biology methods for producing new biomolecules, genetic engineering is paving the way for new developments in medication discovery. The therapeutic toolkit for treating complicated illnesses is growing thanks to these advancements (Zahedipour et al., 2024). Precision medicine is evolving due to the incorporation of genetic engineering into pharmacological research, which has the potential to completely transform healthcare. Genetic engineering is changing the future of medicine by facilitating the creation of customized treatments, treating diseases that were previously incurable, and improving our comprehension of disease mechanisms. But achieving this goal will entail overcoming obstacles related to accessibility, ethics, and technology. Additionally, it necessitates consistent funding for research, interdisciplinary cooperation, and a dedication to healthcare equity. The promise of precision medicine—a world where therapies are customized to each person's own genetic makeup—becomes more real as the discipline develops.

Recognition The author expresses gratitude to Genesis Research Consultancy Limited's Research and Development Wing for its financial and logistical support. Statement of ethical approbation Nothing to report. Data accessibility is not relevant. Statement of informed consent Not relevant. Conflict of interest No conflicting interests are disclosed by the writers. Contribution of the authors This editorial was conceptualized and written with assistance from Md. Mosharraf Hossen. The final draft of the published editorial has been reviewed and approved by the author.

References

Chen SQ, Ahmed S, Zhou Z, and Zhou J (2016). Precision medicine can benefit from pharmacogenomics of drug-metabolizing enzymes and transporters. Bioinformatics, Proteomics, and Genomics, 14(5): 298–313. https://doi.org/10.1016/j.gpb.2016.03.008 Tambuwala MM, El-Tanani M, and Aljabali AAA, 2024. The fundamentals of CRISPR-Cas9 technology include developments in medicine delivery and genome editing. Almeida M and Ranisch R, Journal of Drug Delivery Science and Technology, 92: 105338. https://doi.org/10.1016/j.jddst.2024.105338. Beyond safety: charting the moral controversy surrounding heritable genome editing treatments. Humanities and Social Sciences Communications, 9: 139.

https://doi.org/10.1057/s41599-022-01147-y Alzoubi L, Tambuwala MM, and Aljabali AAA, 2023. Enhancing precision medicine: How 3D printing affects individualized treatment. AAPS PharmSciTech, 24(8): 228. https://doi.org/10.1208/s12249-023-02682-w Banerjee A and Ward V, 2022. microalgae that produce therapeutic and recombinant proteins. Biotechnology Current Opinion, 78: 102784..2022.102784 Bulcha JT, Wang Y, Ma H, Tai PWL, and Gao G, 2021. Viral vector platforms in the context of gene therapy. Targeted Therapy and Signal Transduction, 6: 53.https://doi.org/10.1038/s41392-021-00487-6 Chakraborty S, Banerjee S, Karmakar S, and Sharma G, 2024. A new era in cancer treatment: multi-OMICS techniques in cancer biology. Molecular Basis of Disease, Biochimica et Biophysica Acta (BBA), 1870(5): 167120.

https://doi.org/10.1016/j.bbadis.2024.167120 Deneault E, 2024. Gene editing has recently been used therapeutically to treat genetic diseases. 4147–4185 in Current Issues in Molecular Biology, 46(5). Doxzen KW, Adair JE, Bazzo FYM, Bukini D, Cornetta K, Dalal V, Guerino-Cunha RL, Hongeng S, Jotwani G, Kityo-Mutuluuza C, Lakshmanan K, Mahlangu J, Makani J, Mathews V, Ozelo MC, Rangarajan S, Scholefield J, Batista SJJ, and McCune JM, 2024. gene therapy's translational gap in low- and middle-income nations. 16(746): eadn1902, Science Translational Medicine. Dutta KK 2024 https://doi.org/10.1126/scitranslmed.adn1902a. The slow identification of microRNAs' cell-type and context specificity. Dutta KK 2024 Journal of Bioscience and Environment Research, 2: 1-3. https://doi.org/10.69517/jber.2024.02.01.0001b. CpG island editing via CRISPR-dCas9: This could revolutionize the treatment of diabetes. Bioscience and Environment Research Journal, 2: 10–13. https://doi.org/10.69517/jber.2025.02.01.0003 Heilbron K, Mozaffari SV, Vacic V, Yue P, Wang W, Shi J, Jubb AM, Pitts SJ, and Wang X, 2021. utilizing the human genome to advance medication discovery. 418–429 in The Journal of Pathology, 254(4). https://doi.org/10.1002/path.5664 Hossam AB, Abdelaal NM, Anwer EKE, Rashwan AA, Hussein MA, Ahmed YF, Khashana R, Hanna MM, and Abdelnaser A, 2024. A thorough analysis of the function of CYP450 enzymes in metabolism and illness. Biomedicines, 12(7): 1467. https://doi.org/10.3390/biomedicines12071467 Hsu PD, Lander ES, and Zhang F, 2014. CRISPR-Cas9 development and genome engineering applications. Cell, 157(6): 1262–1278. https://doi.org/10.1016/j.cell.2014.05.010 Jamrat S, Sukasem C, Sratthaphut L, Hongkaew Y, and Samanchuen T, 2023. Using both genetic and nongenetic elements for clinical decision-making, precision medicine offers individualized prescriptions. 165: 107329 Computers in Biology and Medicine. https://doi.org/10.1016/j.compbiomed.2023.107329 Marques L, Costa B, Pereira M, Silva A, Santos J, Saldanha L, Silva I, Magalhães P, Schmidt S, and Vale N, 2024. Precision medicine advancement: An overview of cutting-edge in silico methods for clinical pharmacology, drug discovery, and individualized treatment.Pharmaceutics, 16(3): 332.

Abrahamse H and Merlin JPJ, 2024. https://doi.org/10.3390/pharmaceutics16030332. Enhancing CRISPR/Cas9 accuracy: Reducing off-target effects to safely combine photodynamic and stem cell therapies for the treatment of cancer. Pharmacotherapy and Biomedicine, 180: 117516. https://doi.org/10.1016/j.biopha.2024.117516 Mohr AE, Ortega-Santos CP, Whisner CM, Klein-Seetharaman J, and Jasbi P, 2024. managing the opportunities and difficulties of integrating multiple omics for individualized healthcare. Biomedicines, 12(7): 1496. https://doi.org/10.3390/biomedicines12071496 Puccetti M, Pariano M, Schoubben A, Giovagnoli S, and Ricci M, 2024. Drug delivery systems using biologics, theranostics, and personalized medicine. Research on Pharmacology, 201: 107086.

https://doi.org/10.1016/j.phrs.2024.107086 Qahwaji R, Ashankyty I, Sannan NS, Hazzazi MS, Basabrain AA, and Mobashir M, 2024. A genetic approach to medication creation and treatment is called pharmacogenomics. Pharmaceuticals, 17(7): 940 Quazi S., 2022.

https://doi.org/10.3390/ph17070940. Machine learning and artificial intelligence in genomic and precision medicine. Medical Oncology, 39(8): 120.
12032-022-0111-1 Rubbini D, Cornet C, Terriente J, and Donato DV, 2020. Zebrafish and CRISPR: Faster identification of novel therapeutic targets. SLAS Discovery, 25(6): 552–567.
https://doi.org/10.1177/2472555220926920 Rubeis G and Steger F, 2018. An ethical study of the advantages and disadvantages of human germline genome editing. Asian Bioethics Review, 10(2), 133-141.
https://doi.org/10.1007/s41649-018-0056-x Strianese O, Rizzo F, Ciccarelli M, Galasso G, D'Agostino Y, Salvati A, Giudice DC, Tesorio P, and Rusciano MR, 2020. Precision and individualized medicine: How the genomic approach enhances the treatment of neurological and cardiovascular conditions. Genes, 11(7): 747.
https://doi.org/10.3390/genes11070747 Sugandh F, Chandio M, Raveena F, Kumar L, Karishma F, Khuwaja S, Memon UA, Bai K, Kashif M, Varrassi G, Khatri M, and Kumar S, 2023. Developments in the treatment of diabetes mellitus: Personalized therapy is the main focus. Cureus, 15(8): e43697.
https://doi.org/10.7759/cureus.43697 Skzodny AC and Lee KH, 2022. Manufacturing of biopharmaceuticals: Historical viewpoints and prospects. Chemical and Biomolecular Engineering Annual Review, 13: 141–165. Wang JY and Doudna JA, 2023
; https://doi.org/10.1146/annurev-chembioeng-092220-125832. CRISPR technology: Genome editing is just getting started after ten years. Science, 379(6629): eadd8643.
https://doi.org/10.1126/science.add8643 Yadav S, Singh A, Singhal R, and Yadav JP, 2024. The impact of artificial intelligence on developments in pharmacology and the pharmaceutical industry is revolutionizing medication discovery. 367–380 in Intelligent Pharmacy, 2(3). https://doi.org/10.1016/j.ipha.2024.02.009 Yu J, Li T, and Zhu J, 2022. techniques for gene therapy that target disorders associated with aging. 398–417 in Aging and Disease, 14(2).
https://doi.org/10.14336/AD.2022.00725 Zahedipour F, Zamani P, Jaafar MR, and Sahebkar A, 2024. Harnessing CRISPR technology for viral treatments and vaccines: from preclinical investigations to clinical applications. Virus Research, 341: 199314. https://doi.org/10.1016/j.virusres.2024.199314