

The Role of Artificial Intelligence in Personalized Medicine and Its Contribution to Targeted Genetic Therapies and Clinical Outcomes

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DESCRIPTION

Artificial intelligence has emerged as a transformative force in genetic engineering, providing powerful tools that enhance precision, efficiency and innovation in the manipulation of genetic material. Genetic engineering involves the modification, deletion, or insertion of specific genes to alter the characteristics of organisms or to treat diseases. Traditionally, these processes relied on experimental trial and error, extensive laboratory work and iterative design cycles. The integration of artificial intelligence into this field has revolutionized the way researchers analyze genetic information, design experiments and predict biological outcomes, enabling faster and more accurate advancements that were previously unattainable.

One of the most significant contributions of artificial intelligence to genetic engineering is in the analysis of large-scale genomic data. Modern sequencing technologies generate vast amounts of information, including the complete DNA sequences of humans, animals, plants and microorganisms. Interpreting these datasets manually is time-consuming and prone to error. Artificial intelligence algorithms can rapidly process and analyze genomic data, identifying mutations, regulatory elements and gene interactions with high accuracy. This capability allows researchers to pinpoint disease-causing genetic variations, discover new gene targets for therapy and design experiments that are guided by predictive models rather than intuition alone.

In the context of therapeutic development, artificial intelligence enhances the design and optimization of gene editing strategies. Technologies such as Clustered Regularly Interspaced Short Palindromic Repeats associated protein nine, base editors and prime editors require careful planning to target specific genomic sites without causing unintended modifications. Artificial intelligence algorithms can predict off-target effects, evaluate the efficiency of potential guide sequences and optimize editing protocols. By simulating genetic interactions computationally, researchers can reduce the number of experimental iterations, saving time and resources while increasing the likelihood of successful gene modifications. This predictive power is

particularly valuable in clinical applications where safety and efficacy are paramount.

Artificial intelligence also facilitates the development of synthetic biological systems, which involve the design of entirely new genetic circuits and metabolic pathways. Constructing such systems requires precise coordination of multiple genes and regulatory elements to achieve desired functions, such as producing therapeutic molecules or biofuels. Machine learning models can predict how genetic modifications will affect cellular behavior, enabling scientists to design complex biological systems with predictable outcomes. This reduces the trial and error traditionally associated with synthetic biology and accelerates the creation of functional organisms that can perform specialized tasks in medicine, agriculture and industry.

Furthermore, artificial intelligence has a profound impact on personalized medicine, where therapies are modified to an individual's genetic profile. By integrating genomic data with clinical information, artificial intelligence can identify patient-specific gene targets, predict responses to therapies and design individualized gene-based interventions. For example, in cancer treatment, artificial intelligence can analyze tumor genomes to identify the mutations driving malignancy and guide the engineering of immune cells to recognize and eliminate tumor cells. Such applications improve treatment precision, minimize adverse effects and expand the potential for curative therapies in previously untreatable conditions.

Artificial intelligence also aids in drug discovery and development associated with genetic engineering. Traditional drug development processes are lengthy and costly, often taking more than a decade to bring a therapy to market. Artificial intelligence can model the interaction between genetic pathways and potential therapeutic compounds, identify candidates with high efficacy and predict toxicity profiles. This accelerates the discovery of gene-based therapies, gene delivery systems and small molecule drugs that complement genetic interventions, streamlining the translation of laboratory research into clinical practice.

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Despite its transformative potential, the integration of artificial intelligence in genetic engineering raises ethical and practical considerations. Ensuring the accuracy of predictive models, preventing biases in datasets and protecting patient privacy are critical challenges. Additionally, as artificial intelligence enables increasingly complex genetic modifications, questions arise regarding the responsible use of these technologies, potential ecological impacts and equitable access to benefits. Establishing regulatory frameworks, promoting transparency and encouraging interdisciplinary collaboration between geneticists, computer scientists, ethicists and clinicians are essential to ensure that artificial intelligence is applied safely and responsibly.

CONCLUSION

In conclusion, artificial intelligence is reshaping the landscape of genetic engineering by enhancing data analysis, guiding gene editing, enabling synthetic biology and supporting personalized medicine. Its predictive and analytical capabilities accelerate research, improve precision and expand the possibilities for innovative therapies and applications. While scientific, ethical and regulatory challenges remain, the continued integration of artificial intelligence into genetic engineering promises to unlock unprecedented opportunities for improving human health, advancing biotechnology and addressing complex biological challenges in a rapidly evolving world.