

**GENETIC ENGINEERING AND BIOTECHNOLOGY: MODERN APPLICATIONS IN  
MEDICINE****Kuriyazova Saodat Matkarimovna**

Associate Professor, Candidate of Biological Sciences,

Tashkent State Medical University

**Muzaparov Azizbek Ulugbekovich and****Isoqov Abduxalim Shamsiddinovich**

Students of Tashkent State Medical University

**Abstract:** Genetik engineering and biotechnology represent transformative forces in modern medicine, reshaping diagnostics, therapeutics, and preventive care. This article explores key advancements, including CRISPR-Cas9 genome editing, gene therapy for inherited disorders, and the biotechnological development of mRNA vaccines. It also examines the integration of personalized medicine, stem cell technologies, and molecular biology in clinical practice. While these innovations hold immense promise, they also raise significant ethical, legal, and social concerns. The article highlights both the opportunities and challenges of genetic engineering in healthcare and concludes with a perspective on future directions in this rapidly evolving field.

**Keywords:** Genetik engineering, Biotechnology, Gene therapy, CRISPR-Cas9, Personalized medicine, Molekular biology.

**Annotatsiya:** Genetik injeneriya va biotexnologiya zamonaviy tibbiyotda tub burilish yasab, kasalliklarni tashxislash, davolash va oldini olish jarayonlarini o'zgartirib yubordi. Ushbu maqolada CRISPR-Cas9 gen tahrirlash texnologiyasi, irsiy kasalliklar uchun gen terapiyasi va mRNA vaksinalarining yaratilishi kabi so'nggi yutuqlar yoritilgan. Shuningdek, biotexnologiyaning shaxsiylashtirilgan tibbiyot va regenerativ terapiyalardagi o'rni tibbiyotda yangi istiqbollarni ochib bermoqda. Shu bilan birga, ushbu innovatsiyalar axloqiy, huquqiy va ijtimoiy muammolarni ham keltirib chiqarmoqda. Maqolada genetik injeneriyaning tibbiyotdagi afzalliklari va cheklovlari tahlil qilinib, kelajak istiqbollari yoritiladi.

**Kalit So'Zlar:** Genetik injeneriya, Biotexnologiya, Gen terapiyasi, CRISPR-Cas9, Shaxsiylashtirilgan tibbiyot, Molekulyar biologiya.

**Аннотация:** Генная инженерия и биотехнология стали ключевыми направлениями современной медицины, радикально изменив подходы к диагностике, лечению и профилактике заболеваний. В статье рассматриваются новейшие достижения, включая редактирование генома с помощью CRISPR-Cas9, генную терапию наследственных заболеваний и разработку мРНК-вакцин. Интеграция биотехнологий в персонализированную медицину и регенеративные методы лечения открывает новые перспективы для здравоохранения. Однако такие инновации сопровождаются этическими, правовыми и социальными проблемами. В статье обсуждаются

преимущества и вызовы применения генной инженерии в медицине, а также перспективы её развития.

**Ключевые Слова:** Генная инженерия, Биотехнология, Генная терапия, CRISPR-Cas9, Персонализированная медицина, Молекулярная биология.

**INTRODUCTION** - Biotechnology and genetic engineering have revolutionized the medical sciences over the past few decades. From the sequencing of the Human Genome Project to the Nobel Prize in Chemistry (2020) awarded for CRISPR-Cas9 technology, these disciplines have provided powerful platforms for understanding and treating human diseases. In modern medicine, the application of biotechnology extends across diagnostics, therapeutics, vaccine development, and regenerative medicine. Genetic engineering, in particular, has paved the way for targeted therapies that were previously unimaginable. This paper aims to analyze the scientific advancements in genetic engineering and biotechnology, their applications in healthcare, and the ethical considerations surrounding their use.

**Methods and Approaches** - Genetic engineering encompasses several molecular techniques designed to modify, repair, or regulate genetic material. Among the most prominent are CRISPR-Cas9, transcription activator-like effector nucleases (TALENs), and zinc-finger nucleases (ZFNs). These technologies allow precise targeting of genomic sequences, enabling corrections of genetic mutations or insertions of new genes. In parallel, biotechnology platforms, including recombinant DNA technology and synthetic biology, facilitate large-scale production of biologics such as monoclonal antibodies and vaccines. Methodological approaches also involve high-throughput sequencing, bioinformatics, and advanced cellular models to evaluate genetic interventions in preclinical and clinical settings.

**Results and Discussion: Gene Therapy-** Gene therapy represents one of the most significant achievements of modern genetic engineering. Approved therapies for spinal muscular atrophy and hemophilia demonstrate the real-world impact of these innovations. In oncology, engineered T-cells, including CAR-T cell therapies, have shown remarkable success in treating refractory cancers. **MRNA Vaccines** - Biotechnology has also transformed preventive medicine through the development of mRNA-based vaccines, most notably against COVID-19, which highlighted the adaptability and speed of this platform. Furthermore, clinical trials are investigating mRNA vaccines for oncology and rare genetic disorders, marking a paradigm shift in preventive and therapeutic strategies. **Stem Cell Applications and Bio printing** - Beyond the existing clinical applications, biotechnology continues to broaden its scope in regenerative medicine. Stem cell-based therapies are being investigated for the treatment of neurodegenerative disorders, cardiovascular disease, and musculoskeletal injuries. Advances in 3D bioprinting of tissues and organs suggest the possibility of developing transplantable biological structures in the near future, potentially addressing the global shortage of donor organs.

**Pharmacogenomics and Personalized Medicine** - Pharmacogenomics, which studies the interaction between genetic variation and drug response, enables the development of tailored treatment regimens that improve efficacy and reduce adverse effects. This shift toward precision medicine not only enhances patient outcomes but also reduces healthcare costs by minimizing ineffective therapies.

**Ethical and Societal Challenges-** Despite these successes, challenges remain. Off-target effects of gene editing raise concerns about unintended genetic consequences. Ethical debates persist regarding germline editing, human cloning, and the potential misuse of biotechnology in

non-therapeutic contexts. Issues such as data privacy in genetic testing and unequal access to advanced therapies necessitate careful regulation. International collaborations are essential to establish guidelines that ensure safe, fair, and ethical use of these powerful technologies.

Conclusion - Genetic engineering and biotechnology are at the forefront of a paradigm shift in medicine. Their potential to prevent, treat, and even cure previously untreatable diseases is unparalleled. While ethical and practical challenges remain, the integration of these technologies into mainstream healthcare is inevitable. The future of medicine will likely be shaped by continued advancements in genetic science, combined with global collaboration to ensure safe, ethical, and equitable applications.

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