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OBJECTIVES AND TASKS OF BIOTECHNOLOGY: GENETIC EDITING AND CRISPR TECHNOLOGY

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Abstract: This article explores one of the most significant breakthroughs in modern biotechnology—genetic editing and CRISPR technology. Gene modification methods, especially the CRISPR-Cas9 system, enable precise and efficient DNA modifications, leading to transformative changes in medicine, agriculture, and environmental sciences. Scientific research confirms the vast potential of this technology in treating hereditary diseases, genetically modifying plants and animals, and opening new opportunities in biomedicine. Furthermore, the paper analyzes the ethical and legal aspects of CRISPR technology, its potential risks, and future challenges.

Keywords: Genetic editing, CRISPR-Cas9, biotechnology, gene modification, DNA alteration, gene therapy, disease treatment, biomedicine, advanced medicine, GMO (genetically modified organisms), mutation, epigenetics, gene expression, future of medicine, human genome project, nano-biology, biosafety and ethics, food security, bioengineering, modern genomics.

Introduction

Genetic editing has recently emerged as one of the most groundbreaking achievements in biology and medicine. The discovery of CRISPR-Cas9 technology has revolutionized genetic engineering. This article discusses the essence of CRISPR technology, its working principles, applications, ethical concerns, and future prospects.

Essence of CRISPR Technology

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) is a technology derived from bacterial immune systems, allowing precise genetic modifications. Inspired by bacteria's natural defense mechanisms against viruses, the CRISPR-Cas9 system enables targeted DNA modifications.

Compared to other gene-editing methods, CRISPR technology stands out for its affordability, simplicity, and efficiency. Traditional methods (e.g., TALEN or ZFN) are expensive and complex, whereas CRISPR's accessibility has facilitated its widespread application in scientific and medical research.

Mechanism of CRISPR Technology

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The CRISPR-Cas9 system operates through the following steps:

1. **Binding of Cas9 protein and guide RNA (gRNA)** – The gRNA directs Cas9 to the target DNA sequence, identifying genes responsible for diseases or harmful mutations. This ensures the precise and effective function of CRISPR technology.
2. **DNA cutting by Cas9 enzyme** – This enables genetic modifications, allowing gene deletion, alteration, or correction.
3. **Genetic editing** – Introduces mutations or integrates new DNA segments.

Besides CRISPR-Cas9, newer variants such as CRISPR-Cas12, CRISPR-Cas13, and CRISPR-Cas14 have been developed for different genetic modifications.

Applications of CRISPR Technology

1. Medicine

- **Treatment of genetic diseases** – Potential cures for anemia, cystic fibrosis, and muscular dystrophy.
  - *Anemia* – Eliminating genetic causes of blood disorders.
  - *Cystic fibrosis* – Correcting genetic defects in the respiratory and digestive systems.
  - *Muscular dystrophy* – Editing mutated genes responsible for the disease.
- **Cancer therapy** – Genetic control over tumor growth.
  - *Suppressing oncogenes* – Deactivating genes that promote cancer growth.
  - *Enhancing immune response* – Genetically modifying immune cells to improve cancer-fighting ability.
- **Viral disease treatment** – Potential cures for HIV, hepatitis, and other viral infections.
  - *HIV* – Reducing or eliminating the virus's impact on human cells.
  - *Hepatitis and other viruses* – Editing viral genomes to prevent their spread.
- **Regenerative medicine** – Laboratory-grown human organs using CRISPR.
  - *Artificial organ creation* – Developing new kidneys, livers, or hearts.
  - *Cell reprogramming* – Generating new cells to repair damaged tissues.

2. Agriculture

- **Increasing crop yield** – Enhancing plant resistance to diseases.
  - *Genetically modified crops* – Making plants resistant to drought, pests, and diseases.
  - *Disease-resistant crops* – Protecting agricultural products from viruses, fungi, and bacteria.
  - *Higher productivity* – Improving growth rates and crop quality using CRISPR.
- **Developing GMO foods** – Improving food quality.

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- *Removing allergens* – Eliminating allergens from peanuts, dairy, etc.
- *Enhancing nutritional content* – Increasing vitamins and minerals in crops.

- **Climate-resilient crops** – Developing drought-tolerant plants.
  - *Drought-resistant crops* – Reducing water consumption needs.
  - *Salt-tolerant crops* – Creating plants suitable for saline soils.

3. Environmental Science

- **Bioremediation** – Creating bacteria to clean polluted environments.
  - *Genetically modified microorganisms* – Using CRISPR to enhance bacteria for environmental cleanup.
  - *Oil and plastic degradation* – Producing bacteria capable of breaking down toxic waste.
- **Conservation of endangered species** – Preserving biodiversity through genetic editing.
  - *Restoring endangered species* – Using gene editing to save at-risk species.
  - *Cloning and genetic diversity preservation* – Preventing species extinction.
  - *Disease-resistant species* – Engineering animals to withstand infections.
- **Controlling disease-spreading insects** – Reducing mosquito populations responsible for malaria.
  - *Genetically sterilized mosquitoes* – Preventing disease transmission.
  - *Eradicating harmful genes* – Reducing populations of disease-carrying insects.

Ethical and Legal Challenges of CRISPR Technology

1. **Genetically modified babies** – Raises ethical concerns about human gene editing.
2. **Hereditary risks** – Genetic changes may be passed on to future generations, necessitating international regulations.
3. **Ecological impact** – Potential risks of GMOs on natural ecosystems.
4. **Genetic discrimination risks** – Employers or insurance companies may misuse genetic data.

Conclusion

CRISPR technology has initiated a revolution in genetic engineering. Its responsible and cautious application can help solve numerous global challenges. However, as the technology advances, ethical and legal considerations remain crucial.

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