Mains Practice Question

Q. What are the potential applications of genetic engineering in agriculture, medicine, and environmental conservation? What ethical concerns do these advancements raise? **(250 words)**

08 May, 2024 GS Paper 3 Science & Technology

Approach

- Introduce the answer with definition of genetic engineering
- Highlight potential applications of genetic engineering
- Mention ethical concerns related to genetic engineering
- Conclude positively.

Introduction

Genetic engineering is the process of manipulating an organism's genetic material, typically by **inserting or deleting specific genes,** to achieve desired traits or characteristics. It holds immense promise for agriculture, medicine, and environmental conservation.

Body

Potential Applications of Genetic Engineering:

- **Agriculture:**
  - **Reduced Reliance on Pesticides:** Engineering pest-resistant crops like **Bt cotton** minimizes the use of harmful insecticides, safeguarding human health and the environment.
  - **Enhanced Food Security**: Engineering crops resistant to diseases (e.g., **Papaya ringspot virus-resistant papaya)** reduces crop loss and increases food production, vital for feeding a growing global population.
    - China is planting **salt-tolerant GM rice** in a salty region on the edge of the **Xinjiang desert**, where most vegetation can't grow to promote food security.

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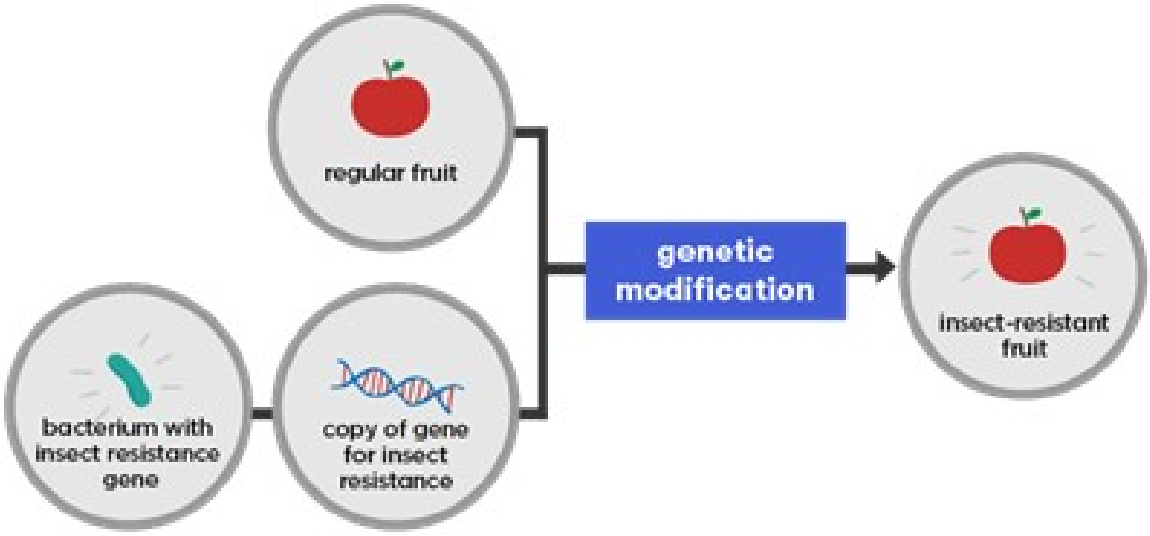

- **Improved Nutritional Value:** Genetically modified crops can be enriched with essential vitamins and minerals, addressing malnutrition, particularly in developing nations.
    - For example, **Golden Rice** is engineered with increased **beta-carotene** to combat Vitamin A deficiency.
- **Improved Shelf Life**: Introducing genes that slow down spoilage can extend the shelf life of fruits and vegetables, reducing food waste and ensuring wider availability of fresh produce.

- **Medicine:**
    - **Gene therapy**: Genetic engineering can potentially treat or cure genetic disorders by introducing **functional genes or correcting defective ones.**
        - Trails for gene therapy for **cystic fibrosis** are going on.
    - **Pharmaceutical production**: Genetically engineered bacteria, yeast, or plants can produce therapeutic proteins, vaccines, and antibodies more efficiently.
        - For example, **yeast** can produce human insulin for diabetics, a significant advancement over animal-derived insulin.
    - **Sickle Cell Disease**: Gene editing techniques are being explored to correct the defective gene responsible for **sickle cell disease.**
    - **Cancer Treatment**: Research is ongoing to use **CAR-T cell therapy,** where a patient's **T cells** are genetically modified to recognize and attack cancer cells.
- **Environment Conservation:**
    - **Bioremediation**: Plants can be genetically modified to absorb pollutants from soil and water, contributing to environmental cleanup efforts.
        - Studies are ongoing to explore the use of **genetically modified Brassica juncea (Indian mustard)** for the bioremediation of soils.
        - Microorganisms engineered to **metabolize oil** can be used to clean up oil spills, minimizing environmental damage.
    - **Conservation of Endangered Species:** Gene banks can store genetic material from endangered species, and genetic engineering techniques may be used to:
        - Introduce genes from closely related species to bolster genetic diversity in small, isolated populations of endangered animals.
    - **Development of Eco-friendly Products:** Genetically engineered organisms can produce:
        - **Biodegradable Plastics:** Microbes can be engineered to create biodegradable plastics that decompose naturally, **reducing plastic pollution.**
        - **Biofuels:** Engineered **algae or yeast** can be used to produce biofuels as a renewable and sustainable energy source.

Ethical Concerns Related to Genetic Engineering:

- **Impact on Biodiversity**: Reliance on a few high-yielding GM varieties can reduce agricultural diversity, making crops more vulnerable to widespread diseases like the **Irish Potato Famine.**

- **Human Enhancement**: The possibility of using gene editing for non-therapeutic purposes, such as enhancing intelligence or athletic performance, raises ethical questions about creating "**designer babies**"
- **Inequitable Access:** The high costs associated with these new technologies could limit access for patients in developing nations, exacerbating **existing healthcare disparities.**
- **Ownership and Control:** Genetic engineering raises questions about ownership and control of genetic information, **patents on genetically modified organisms**, and the commercialization of genetic technologies.

Conclusion

To address these ethical concerns, principles such as **beneficence, non-maleficence, autonomy, and justice** should guide the development and application of genetic engineering technologies to ensure **responsible and equitable use** for the greater **good of humanity and the environment.**