



Genetically Modified Organism (GMO)

For Prelims: [Genetically Modified Organism \(GMO\)](#), [DNA](#), [Genetic Engineering Appraisal Committee \(GEAC\)](#), Recombinant DNA Technology, CRISPR-Cas9 system, RNA interference (RNAi), Somatic Cell Nuclear Transfer (Cloning).

For Mains: Implication of Genetically Modified Organism (GMO) on Human Health.

What is Genetically Modified Organism (GMO)?

- **About:**
 - A [genetically modified organism \(GMO\)](#) refers to an entity, whether it's an **animal, plant, or microorganism**, that has undergone modifications to its [DNA](#) using **genetic engineering methods**.
 - Across generations, specific traits have been cultivated in **crops like corn, animals like cattle**, and even **domestic companions like dogs** through **selective breeding**. Yet, in recent decades, the progress of biotechnology has enabled researchers to directly manipulate the **genetic makeup of microorganisms, plants, and animals**.
- **Genetic Modification:**
 - It involves altering the **DNA** of an organism to introduce **specific traits or characteristics**. There are several techniques used in **genetic modification**, each with its own advantages and applications.

What is the Genetic Engineering Appraisal Committee (GEAC)?

- The [Genetic Engineering Appraisal Committee \(GEAC\)](#) functions in the [Ministry of Environment, Forest and Climate Change \(MoEF&CC\)](#).
- It is responsible for **appraisal** of activities involving large scale use of **hazardous microorganisms and recombinants** in research and industrial production from the environmental angle.
- The committee is also responsible for appraisal of proposals relating to release of **genetically engineered (GE) organisms and products** into the environment including experimental field trials.
- **GEAC** is chaired by the **Special Secretary/Additional Secretary** of **MoEF&CC** and co-chaired by a representative from the **Department of Biotechnology (DBT)**. Presently, it has **24 members** and meets every month to review the applications in the areas indicated above.

What are the Important Gene Editing Techniques?

- **Recombinant DNA Technology:** This technique involves **isolating and cutting** specific **DNA segments** from **one organism (source)** and inserting them into the **DNA of another organism (host)**. The **host organism** then incorporates the **new DNA** into its **genome**, expressing the desired trait. This technique is widely used in producing **genetically modified crops** and [pharmaceuticals](#).
- **CRISPR-Cas9:** The [CRISPR-Cas9 system](#) is a revolutionary gene editing tool that allows

scientists to **precisely target** and **modify specific DNA sequences**. It can be used to **add, delete, or replace genes** in a wide range of **organisms**, from **bacteria to plants and animals**.

- **TALENs (Transcription Activator-Like Effector Nucleases):** TALENs are another **gene editing technique** that can be programmed to target specific **DNA sequences**. They work similarly to **CRISPR-Cas9** and have been used for **genetic modification** in various organisms.
- **RNA Interference (RNAi):** [RNA interference \(RNAi\)](#) is a **natural cellular process** that plays a crucial role in regulating **gene expression** within **eukaryotic cells**. This triggers the degradation of the target gene's [messenger RNA \(mRNA\)](#), resulting in reduced **expression** of the corresponding protein.
- **Somatic Cell Nuclear Transfer (Cloning):** This technique involves **transferring the nucleus of a somatic cell** (any cell except sperm or egg cells) into an **egg cell** from which the **nucleus** has been removed. This process creates a **genetically identical organism (clone)**. **Dolly the sheep** was famously created using [somatic cell nuclear transfer](#).
- **Synthetic Biology:** [Synthetic biology](#) involves **designing and constructing new biological parts, devices, and systems**, as well as **redesigning existing biological systems**. It often includes the **synthesis of DNA sequences, modifying existing genes, and constructing novel genetic circuits**.
- **Viral Vectors:** It is **modified viruses** that can carry **specific genes** into **target cells**. They are used in [gene therapy](#) to deliver **therapeutic genes** to **treat genetic disorders**.
- **Selectable Markers and Reporter Genes:** These are genes introduced alongside the desired gene to assist in the **identification and selection of genetically modified organisms**. Selectable markers confer resistance to **specific antibiotics or chemicals**, while reporter genes produce easily detectable proteins (e.g., fluorescent proteins) to indicate successful gene transfer.
- **Agrobacterium-Mediated Transformation:** This method uses the natural ability of the **bacterium Agrobacterium tumefaciens** to transfer genetic material into plants. The bacterium is engineered to carry the desired gene, and when it infects the plant, the gene is integrated into the plant's genome.
- **Microinjection:** This technique involves using a **fine needle to inject foreign DNA** directly into the nucleus of a target cell. It is often used in animal genetic modification.
- **Electroporation:** Cells are exposed to an **electric field**, which temporarily disrupts the **cell membrane**, allowing **foreign DNA** to enter.

What are the Advantages of Gene Editing ?

- **Precision in Genetic Modification:** **Gene editing** allows for **highly precise changes** to be made to an **organism's DNA**. This precision can **target specific genes or genetic sequences** with **accuracy**.
- **Agricultural Advancements:** **Gene editing** can be applied to **crops and livestock** to enhance their characteristics, such as **increased yield, disease resistance, or nutritional content**, potentially addressing food security and sustainability challenges.
- **Agricultural Advancements:** It can be applied to **crops and livestock** to enhance their characteristics, such as increased **yield, disease resistance, or nutritional content**, potentially addressing **food security and sustainability challenges**.
- **Reduced Use of Chemicals:** In **agriculture, genetically modified crops** created through **gene editing** could require **fewer pesticides and herbicides, benefiting** both the **environment and human health**.

What are Genetically Modified (GM) Plants?

- **GM plants** are plants that have undergone intentional alteration of their **genetic material** through **genetic engineering techniques**. These modifications are carried out to **introduce specific traits or characteristics** that may not naturally occur within the plant's genome. For example:
 - **Bt Cotton:** [Bacillus Thuringiensis \(Bt\) cotton](#) is engineered to produce a **protein** from the **bacterium Bacillus Thuringiensis** that is toxic to certain **insect pests**. The **bacteria** release **specialized proteins** referred to as "**cry proteins**," which exhibit **toxicity towards insects**. This trait reduces the need for **chemical insecticides** and helps protect the **cotton crop** from damage.
 - **Golden Rice:** Golden rice is modified to produce higher levels of [beta-carotene](#), a

precursor of **vitamin A**. This modification aims to address **vitamin A deficiency**, a major public health concern in many developing countries.

- **Drought-Resistant Crops:** Some plants have been engineered to **tolerate drought conditions** better by introducing genes that help the **plant conserve water or withstand dehydration stress**.
- **Insect-Resistant Eggplant (Bt Brinjal):** Similar to **Bt cotton**, **Bt brinjal** (eggplant) produces a **protein** toxic to certain insect pests. This modification reduces the need for **chemical insecticides**, benefiting both **farmers and the environment**.
- **Papaya Ringspot Virus-Resistant Papaya:** **Hawaiian papaya crops** were genetically modified to **resist the papaya ringspot virus**, which had previously devastated **papaya** production in **Hawaii**.
- **Flavr Savr Tomato:** The **Flavr Savr tomato** was one of the first **genetically modified foods**. It was engineered to have a **longer shelf life** by suppressing the gene responsible for **softening and decay**.
- **Resistant Cassava:** **Cassava**, a **staple crop** in many parts of the world, has been modified to **resist viral diseases** that can significantly reduce yields.
- **Frost-Tolerant Strawberries:** **Strawberries** have been genetically modified to **tolerate frost**, allowing for extended growing seasons in **colder climates**.
- **Non-Browning Apples:** Apples have been engineered to **resist browning** when **sliced or bruised**, which can help **reduce food waste** and increase their **shelf life**.

What are Genetically Modified Medicines?

- **GM medicines**, also known as **biopharmaceuticals** or **biologic drugs**, are **pharmaceutical products** produced using **genetic engineering techniques**. These drugs are derived from **living organisms**, such as **bacteria, yeast, or mammalian cells**, that have been genetically modified to produce **therapeutic proteins** or other **bioactive molecules**.
 - **Insulin:** **Recombinant DNA technology** has been used to produce **insulin** for the **treatment of diabetes**. **Human insulin genes** are inserted into **bacterial or yeast cells**, which then produce **insulin** that is identical to the **naturally occurring hormone**.
 - **Human Growth Hormone (HGH):** **Genetically modified bacteria or mammalian cells** are used to produce **synthetic human growth hormone**, which is used to **treat growth disorders in children and hormone deficiencies in adults**.
 - **Erythropoietin (EPO):** **EPO**, a hormone that stimulates the production of **Red Blood Cells (RBC)**, is produced using **genetically modified mammalian cells**. It is used to **treat anemia** associated with conditions such as **kidney disease and chemotherapy**.
 - **Monoclonal Antibodies:** These are a class of **genetically engineered proteins** used to treat various diseases, including **cancer, autoimmune disorders, and inflammatory conditions**. Monoclonal antibodies are produced by **modifying mammalian cells** to produce **specific antibodies** that target **disease-related molecules**.
 - **Blood Clotting Factors:** Genetically modified cells are used to produce **blood clotting factors**, such as **Factor VIII** and **Factor IX**, for the treatment of **hemophilia**.
 - **Vaccines:** Some **vaccines** are produced using **genetically modified organisms**, such as **yeast or bacteria**, to **express antigens** that stimulate an immune response. For example, the **hepatitis B vaccine** is produced using **genetically modified yeast cells**.
 - **Enzyme Replacement Therapies:** **Genetic engineering** is used to produce **enzymes** that are deficient or absent in certain **genetic disorders**. For instance, **enzyme replacement therapies** are used to treat conditions like **Gaucher's disease** and **Fabry disease**.
 - **Cancer Therapies:** **Genetically modified T cells** (a type of immune cell) are being developed as a form of **immunotherapy** for certain types of **cancer**. These modified **T cells** are engineered to **express Chimeric Antigen Receptors (CARs)** that target **cancer cells**.
 - **Clot-Dissolving Agents:** **Genetically modified bacteria or yeast** can be used to produce **clot-dissolving enzymes**, such as **tissue plasminogen activator (tPA)**, which is used in the treatment of certain types of **strokes** and **heart attacks**.

What are Genetically Modified Animals?

- **Genetically modified (GM) animals** are those that have been deliberately modified through **genetic engineering methods**, aiming to incorporate particular traits or features that might not exist naturally in the **animal's genetic makeup**.
 - **GloFish:** GloFish are **genetically modified zebrafish** that have been engineered to express **fluorescent proteins** from **jellyfish** and **coral**. These fish are used in scientific research and as pets to study **genetic traits** and **environmental pollutants**.
 - **AquAdvantage Salmon:** These **salmon** have been **genetically modified** to **grow faster** and **reach market size** more **quickly**. They contain genes from **Chinook salmon** and **ocean pout**, allowing them to produce **growth hormone year-round**.
 - **Enviropig: Enviropigs** have been genetically modified to produce **less phosphorus** in their **waste**, potentially reducing the **environmental impact** of **pig farming** on **water quality**.
 - **Knockout Mice: Mice** are often genetically modified to have specific genes "**knocked out**" or **deactivated**. This allows researchers to study the **effects of gene function** and **develop models** for **human diseases**.
 - **Transgenic Goats:** Goats have been engineered to produce certain **proteins in their milk** that can be extracted and used for **pharmaceutical purposes**. For example, **transgenic goats** can produce **antithrombin, a protein** used in **blood clotting disorders**.
 - **Genetically Modified Mosquitoes:** Mosquitoes have been genetically modified to reduce their ability to **transmit diseases** like **malaria** and **dengue fever**. **Modified mosquitoes** can be engineered to carry a gene that prevents the development of the **disease-causing parasite**.
 - **Dolly the Sheep:** Dolly was the **first mammal cloned** from an **adult somatic cell** using a technique called **somatic cell nuclear transfer**. While not a **traditional genetic modification**, **cloning involves** altering the genetic makeup of an **organism** through a different process.
 - **Genetically Modified Pigs for Organ Transplants: Pigs** have been modified to express **human genes** in their organs, with the **goal of making their organs suitable for transplantation** into **humans** (**xenotransplantation**).
 - **Featherless Chickens:** Some **genetically modified chickens** have been **bred** to have **fewer feathers**, which could reduce the need for plucking during processing.
 - **Spider Silk-Producing Goats:** Certain goats have been **genetically modified to produce spider silk proteins** in their **milk**. These **proteins** can be used to **create strong** and **lightweight materials**.

What is the status of Genetically Modified Organisms in India?

- **Bt Cotton:**
 - Indian farmers started cultivating **Bt cotton**, a **pest-resistant, genetically modified** version of cotton, in **2002-03**.
 - **Bt modification** is a type of genetic modification where the **Bt gene** is obtained from the soil bacterium **Bacillus Thuringiensis**.
 - It has been **genetically modified (GM)** to produce an **insecticide to combat the cotton bollworm, a common pest**.
 - **Bt cotton** is resistant to **bollworm**, a pest that destroys **cotton plants**.
 - By **2014**, around **96%** of the area under cotton cultivation in India was **Bt cotton**.
 - It makes India the **fourth-largest** cultivator of **GM crops** by acreage and the **second largest** producer of **cotton**.
 - **Bt cotton** is the only **transgenic crop** that has been approved by the **Centre for commercial cultivation in India**.
- **GM mustard:**
 - **GEAC** recently approved **commercial cultivation of genetically modified mustard**.
 - **Dhara Mustard Hybrid (DMH -11)** was developed by a team of scientists at Delhi University.
 - It uses a **system of genes** from **soil bacterium** that makes mustard generally a **self-pollinating** plant better suited to hybridisation than current methods.
 - In September 2017, a feasibility report said that the developers of DMH-11 claimed a yield

increase of **25-30%** over **non-hybrids**, which was refuted by several NGOs.

- The **GEAC** cleared **“the environmental release of mustard hybrid DMH-11** for its seed production and testing as per existing **ICAR guidelines** and other extant **rules/regulations** prior to commercial release.
- **Bt Brinjal:**
 - The **GEAC** in **2007**, recommended the commercial release of **Bt Brinjal**.
 - It was developed by **Maharashtra Hybrid Seeds Company** in collaboration with the **University of Agricultural Sciences, Dharwad** and the **Tamil Nadu Agricultural University**.
 - **India** has banned the cultivation of **Bt brinjal** in **2010**.
 - This initiative was **blocked** in **2010**.

What is the Regulatory Framework in India?

▪ Institutions:

- All the activities, operations and products related to the **genetically modified organisms** are regulated by the **Ministry of Environment, Forest and Climate**.
- It is regulated under the **Environment (Protection) Act, 1986**.
- **Genetic Engineering Appraisal Committee (GEAC)** under **MoEFCC** is authorized to review, monitor and approve all activities of **GMO**.
- These activities include **import, export, transport, manufacture, use or sale of GMO**.
- **GM foods** are also subjected to regulations of **Food Safety and Standards Authority of India (FSSAI)**.

▪ Acts and rules:

- **Environment Protection Act, 1986 (EPA)**
 - The **Genetic Engineering Appraisal Committee (GEAC)** serves as the **principal regulatory authority** for biotechnology in India. Operating as a **statutory body**, it operates under the purview of the **Ministry of Environment, Forests and Climate Change (MoEFCC)** and is established in accordance with the **Environment Protection Act, 1986**.
- **Biological Diversity Act, 2002**
 - Under the **Act**, any organization or individual seeking to access **Indian biological resources**, including those for **GMO** research or commercialization, is required to obtain prior approval and enter into **benefit-sharing agreements** with the **National Biodiversity Authority (NBA)**.
 - The **Act** aims to ensure that the **benefits arising from the utilization of these resources** are **shared fairly** with **local communities** and **indigenous people**.
- **Plant Quarantine Order, 2003**
 - The **Plant Quarantine Order, 2003**, includes provisions for **regulating the import and export of GMOs**, including **genetically modified (GM) plants and plant materials**.
- **Food Safety and Standards Act, 2006**
 - The **Food Safety and Standards Act, 2006**, empowers the **Food Safety and Standards Authority of India (FSSAI)** to establish safety standards for food products, including those derived from **GMOs**. It includes provisions for conducting safety assessments to determine the suitability of **GMO-derived foods for human consumption**.

What are the Conventions Related to Genetically Modified Organisms?

▪ Convention on Biological Diversity (CBD):

- It is a **legally binding treaty** to conserve **biodiversity**.
- **Objectives:**
 - The conservation of **biological diversity**.
 - The **sustainable use** of the components of **biological diversity**.
 - The **fair and equitable sharing** of the benefits arising out of the utilization of **genetic resources**.
- **Secretariat:** Montreal, Canada.
 - It operates under the **United Nations Environment Programme**.

- **The Cartagena Protocol on Biosafety:**
 - It primarily deals with the **transboundary movement of living modified organisms (LMOs)**, it includes provisions related to the **handling, transport, and use of GMOs**, which can include **GMOs** in animals.
 - The **Cartagena Protocol on Biosafety**, a supplement to the **Convention on Biological Diversity**.
 - It was approved in **2000**.
 - It came into force in **2003**.
- **Nagoya Protocol:**
 - Access to **Genetic Resources** and the **Fair and Equitable Sharing of Benefits** Arising from their Utilization **Genetically Modified Organisms (GMO)**.
 - It was adopted in **2010** in **Nagoya, Japan** at **COP10**.
 - **Nagoya Protocol** entered into force in **2014**.

What are the Concerns Associated with the GMO?

- **Environmental Impact:** One of the major concerns is the potential for **GMOs** to have **unintended and irreversible effects** on the **environment**. There is a fear that genetically modified crops could **crossbreed** with **wild relatives**, potentially creating **invasive species or altering natural ecosystems**.
- **Biodiversity:** The introduction of **GMOs** can impact **biodiversity** by potentially reducing the diversity of plant and animal species. This could happen if **GMOs** outcompete **Non-GMO** species or if the use of **GMOs** leads to a reduction in traditional, locally adapted crop varieties.
- **Unintended Consequences:** Genetic modifications may have unintended consequences that are **difficult to predict**, such as producing **allergens** or **toxins** that were not initially identified during testing.
- **Health Concerns:** Some people are concerned about the **potential effects of consuming GMOs** on human health. While **GMOs** currently on the market have undergone rigorous safety assessments, some worry that long-term health effects may not be fully understood.
- **Corporate Control and Monopoly:** A significant ethical concern is the **concentration of power and control over the food supply** in the hands of a few large corporations. The patenting of **GMOs** allows companies to have exclusive rights to these **genetic modifications**, potentially limiting access to seeds and forcing farmers into dependency on a few suppliers.
- **Labeling and Consumer Choice:** Many people believe that they have a right to know whether the products they consume contain **GMOs**. The lack of mandatory labeling in some regions has led to concerns about **transparency** and the ability of consumers to make informed choices.
- **Social and Economic Impacts:** The adoption of **GMOs** can have complex **social and economic implications**, particularly in developing countries. While **GMOs** have the potential to increase **crop yields** and **improve food security**, concerns exist about the impact on **small-scale farmers** and **traditional farming practices**.
- **Ethical Treatment of Animals:** Genetic modification is not **limited to crops**; it also involves modifying animals for various purposes, such as **enhancing livestock productivity**. Ethical concerns arise about the **welfare** and **treatment** of these **genetically modified animals**.
- **Cross-Contamination:** The inadvertent mixing of **GMOs** with non-GMO crops is a concern, as it can lead to **unintended GMO presence in organic or non-GMO crops**, which can affect markets that demand **GMO-free products**.
- **Long-Term Effects:** Predicting the **long-term effects of GMOs** on **ecosystems, human health, and society** is challenging. The rapid pace of genetic engineering may outpace our understanding of potential risks.

Way Forward:

- **Comprehensive Risk Assessment:** Continue to conduct **rigorous and transparent risk assessments** of **GMOs** before they are released into the environment or the market. This includes evaluating **potential environmental impacts, human health risks, and unintended consequences**.
- **Transparency and Labeling:** Implement clear and mandatory labeling of **GMO** products to allow consumers to make informed choices. This promotes **transparency** and respects **consumer rights** to know what they are **purchasing and consuming**.

- **Research and Development:** Invest in further research to better understand the **long-term effects of GMOs** on the **environment, biodiversity, human health, and social systems**. Collaborative efforts involving **scientists, regulators, and stakeholders** can help ensure that risks are adequately addressed.
- **Bioethics and Public Engagement:** Involve a diverse range of stakeholders, including **scientists, ethicists, farmers, consumers, and NGOs**, in discussions about the development and deployment of **GMOs**. This participatory approach can help ensure that various perspectives are considered and ethical concerns are adequately addressed.
- **Environmental Monitoring:** Establish ongoing monitoring systems to track the **environmental and health impacts of GMOs** once they are released. This would allow for timely **detection and management** of any **unexpected issues**.
- **Sustainable Agriculture:** Focus on developing **GMOs** that contribute to **sustainable agricultural practices**, such as **crops** with increased **drought** or **pest resistance**, **reduced need for chemical inputs**, and **improved nutritional content**.
- **Biodiversity Protection:** Design **GMOs** in a way that minimizes their **potential to negatively impact biodiversity**. This could involve implementing **containment measures**, selecting traits that have a **low risk of causing harm**, and using **gene editing techniques** that have fewer **off-target effects**.
- **International Collaboration:** Establish **international agreements and guidelines** for the **development, testing, and trade of GMOs**. This would ensure **consistent standards** and **regulatory approaches** across countries and facilitate the responsible use of **GMOs** globally.

UPSC Civil Services Examination Previous Year Question (PYQ)

Prelim:

Q. Consider the following statements:

1. Genetic changes can be introduced in the cells that produce eggs or sperms of a prospective parent.
2. A person's genome can be edited before birth at the early embryonic stage.
3. Human induced pluripotent stem cells can be injected into the embryo of a pig.

Which of the statements given above is/are correct?

- (a) 1 only
 (b) 2 and 3 only
 (c) 2 only
 (d) 1, 2 and 3

Ans: (d)

Mains:

Q: What are the research and developmental achievements in applied biotechnology? How will these achievements help to uplift the poorer sections of the society? **(2021)**