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)**