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THEMATIC #6 CURRENT AFFAIRS

for IAS PRELIMS 2024

SCIENCE & TECHNOLOGY

THEME # 1

Application of Biotechnology

- GENOME EDITING
- BIOTECHNOLOGY & CELLS
- BIOTECHNOLOGY & GOVERNMENT INITIATIVES
- VACCINES
- IMPORTANT TECHNIQUES

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1

Genome Editing

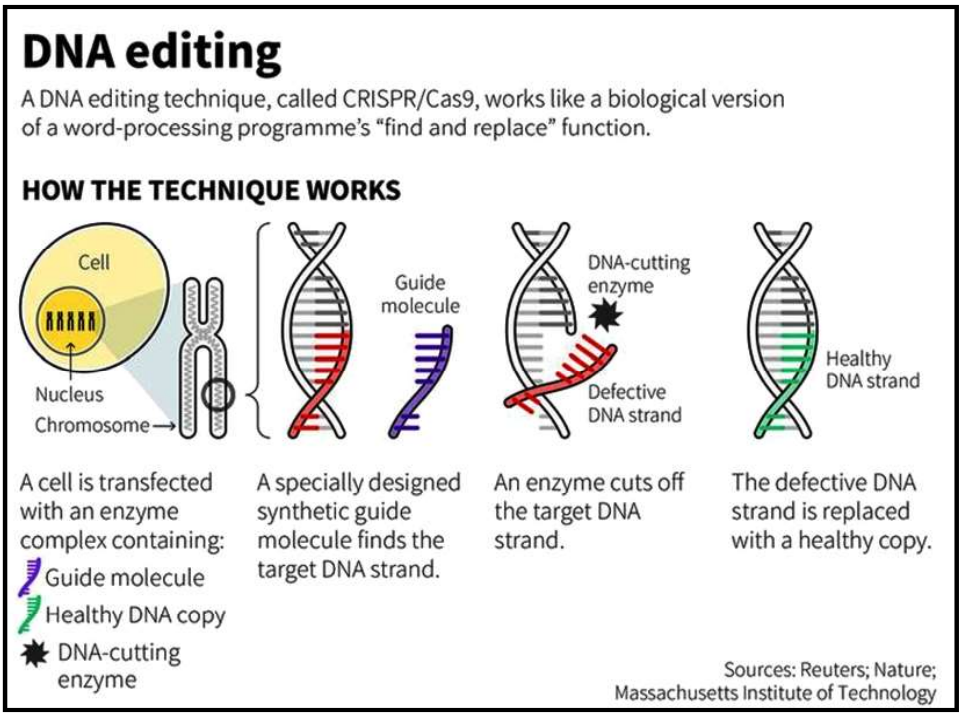
1. GENOME EDITING AND RECENT DEVELOPMENTS

CONTEXT

Over the last few years, gene-editing technology has produced flawless results in clinical trials. India has approved a 5-year project to develop CRISPR to cure **sickle cell anemia.**

What is Genome Editing?

- **Genome editing (also called gene editing)** is a group of technologies that give scientists the ability to change an organism's **Deoxy-Ribonucleic Acid (DNA).**
- These technologies allow genetic material to be **added, removed, or altered** at particular locations in the **genome.**
- Advanced research has allowed scientists to develop the highly effective **Clustered Regularly Interspaced Palindromic Repeat (CRISPR)**, associated proteins-based systems.
- This system allows for **targeted intervention** at the genome sequence.
- It is currently the



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simplest, most versatile, and most precise method of genetic manipulation, causing a buzz in the science world.

About CRISPR technology:

- CRISPR is short for **Clustered Regularly Interspaced Short Palindromic Repeats**.
- It is a reference to the *clustered and repetitive sequences of DNA* found in bacteria, whose natural mechanism to fight some viral diseases is replicated in this gene-editing tool.
- In popular usage, "**CRISPR" (pronounced "crisper")** is shorthand for "**CRISPR-Cas9**." CRISPRs are specialized stretches of DNA, and the **protein Cas9**, where **Cas stands for "CRISPR-associated",** is an enzyme that acts like a pair of molecular scissors, capable of cutting strands of DNA.
- CRISPR is a powerful tool for editing genomes, allowing researchers to easily alter DNA sequences and modify gene function.

CSIR's Institute of Genomics and Integrative Biology has indigenously developed a **CRISPR-based therapeutic solution for sickle cell anaemia**, which is now being readied for clinical trials.

CRISPR: Timeline of Key Events:

- **December 1987:** The CRISPR mechanism was first published.
- **March 2002:** The term CRISPR-Cas9 was published for the first time
- **March 2005**: ***Jennifer Doudna*** and Jillian Banfield started investigating CRISPR.
- **Nov 2005:** American researchers identified new families of Cas genes which appeared to help in protecting bacteria against invading viruses.
- **March 2011:** ***Emmanuelle Charpentier*** and Jennifer Doudna joined forces to investigate Cas9 enzyme.
- **April 2012:** First commercialization of CRISPR-Cas 9 technology.
- **January 2013**: CRISPR-Cas is used in human genome editing.
- **May 2015:** The first report of genes edited in human embryos ignited the global ethical debate about gene editing technology.
- **October 2015**: UNESCO's International Bioethics Committee called for a ban on genetic editing of the human germline.
- **November 2015:** US scientists genetically modified mosquitos using CRISPR/Cas9 to prevent them from carrying malaria parasites.
- **August 2018**: First CRISPR-Cas9 clinical trial launched.
- **December 2018:** CRISPR-Cas9 editing helped restore the effectiveness of first-line chemotherapies for lung cancer.
- **October 2020**: **Nobel Prize in Chemistry** awarded to **Emmanuelle Charpentier** and **Jennifer Doudna** 'for the development of a method for genome editing.

2. GENOMIC SURVEILLANCE

CONTEXT

Recently, **WHO' Science Council** released a report "**Accelerating access to genomics for global health"** advocating for passing on **Genomic Technologies** to developing countries.

About Genomic technologies

- Genomic technologies are technologies used to manipulate and analyze genomic information.
- The field of genomics uses biochemistry, genetics and molecular biology methods to understand and use biological information in **deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).**
- This information benefits medicine and public health — especially during the COVID-19 pandemic — as well as agriculture, biological research and more.

What is genome sequencing?

- **Genome:** It is an organism's complete set of DNA, including all of its genes.
  - Each genome contains all of the information needed to build and maintain that organism. In humans, a copy of the entire genome—more than **3 billion DNA base pairs—**is contained in all cells that have a nucleus.
- **Genome sequencing:** It is figuring out the order of DNA nucleotides, or bases, in a genome—t**he order of As, Cs, Gs, and Ts** that make up an organism's DNA.
- Sequencing the genome doesn't immediately lay open the genetic information of an entire species. Even with a rough draft of the human genome sequence in hand, much work remains to be done. Scientists still have to translate those strings of letters into an understanding of how the genome works.

3. XENOTRANSPLANTATION

CONTEXT

Genetically modified pig heart took longer than usual to beat for human receiver in **the first-ever transplant of the gene-edited pig heart to human**. The human recipient lived only for 61 days after the transplant.

- Prior attempts at such transplants have also failed.

What is Xenotransplantation?

- Xenotransplantation involves the **transplantation of nonhuman tissues** or organs **into human recipients.**

- In the recent heart transplant from pig to human, **gene-editing** was adopted to remove a sugar in its cells that's responsible for that hyper-fast organ rejection.

- Genome editing (also called **gene editing)** is a group of technologies that give scientists the ability to change an organism's **Deoxy-Ribonucleic Acid (DNA).**
- One of the **biggest obstacles** to transplantation is **organ rejection.**

4. GENETICALLY ENGINEERED MOSQUITOES

CONTEXT

Preliminary results of an **open-air study of genetically engineered mosquitoes** — with an aim to suppress a wild population of **virus-carrying mosquitoes** — in the United States have shown promising results.

About Genetically Modified Mosquito:

- A genetically modified insect is an insect that has been **genetically modified** for various reasons such as **agricultural production, oil production and pest control.**
- Scientists have moved on from using **bed nets and insecticides** to kill **malaria-spreading mosquitoes**, to genetically modify the mosquitoes by inserting a gene that leads to the production of male offsprings.
- Since **only females carry the malaria-causing microorganism**, the spread of the disease is controlled in the short-term while eventually the whole population gets wiped out.
- Scientists **injected a gene from a slime mould into the mosquito** which attached itself to the **X chromosome** during sperm-making process effectively masking the sperms leading to production of male offspring.

How GM mosquitoes are produced and used to control *Ae. aegypti* mosquitoes?

- GM mosquitoes are mass-produced in a laboratory to carry two types of genes:
- A **self-limiting gene** that prevents female mosquito offspring from surviving to adulthood.
- A **fluorescent marker gene** that glows under a special red light. This allows researchers to identify GM mosquitoes in the wild.
- GM mosquitoes produced in the laboratory lay eggs. These **eggs carry the self-limiting and fluorescent marker genes.**
- GM mosquito eggs that **carry the self-limiting gene** are released into an area. Once they have hatched and develop through to the adult stage, they are available to mate with wild females. The **genes are passed on to offspring**.
- The **female offspring die before they become adults**. The expected result is that the number of Ae. aegypti mosquitoes in the area decreases.

5. GENETICALLY MODIFIED (GM) CROPS

CONTEXT

A notification by the food safety regulatory body of India Food Safety and Standards Authority of India (FSSAI) over genetically modified organisms (GMO) has received several objections from a pan-Indian citizen's platform.

What is GM Crop?

- A GM or transgenic crop is a plant that has a novel combination of genetic material obtained through the use of modern biotechnology.
- **For example,** a GM crop can contain a gene(s) that has been artificially inserted instead of the plant acquiring it through pollination.

Why GM Crops are significant?

- In the developed world, there is clear evidence that the use of GM crops has resulted in significant benefits. These include:
  - Higher crop yields
  - Reduced farm costs
  - Increased farm profit
  - Safer environment
  - More nutritious food

How they are made?

- GM crops are made through a process known **as genetic engineering.**
- Genes of commercial interest are transferred from one organism to another.
- Two primary methods currently exist for introducing transgenes into plant genomes-:
  - The first involves a device called a '**gene gun'**.
  - The DNA to be introduced into the plant cells is coated onto tiny particles of gold or tungsten.
- These particles are then physically shot onto plant cells and incorporated into the genomic DNA of the recipient plant.
- The second method uses a bacterium to introduce the gene(s) of interest into the plant DNA.

6. GENETICALLY MODIFIED MUSTARD

CONTEXT

Recently, the **Genetic Engineering Appraisal Committee (GEAC)** under the **Union Ministry of Environment, Forest and Climate Change** recommended the "environmental release" of the **transgenic hybrid mustard DMH-11** for seed production and ordered to conduct the field demonstration studies with respect to its effects on honey bees and other pollinating insects.

About GM-Mustard:

- The **hybrid mustard DMH-11** has been produced which contains two alien genes isolated from a soil bacterium called Bacillus '**amyloliquefaciens'.**
- **Barnase:** The first gene ('barnase') codes for a protein that **impairs pollen production** and renders the plant into which it is incorporated **male-sterile.**
- **Barstar:** This plant is then crossed with a fertile parental line containing, in turn, the second 'barstar' gene that blocks the action of the barnase gene.
- The resultant **F1 progeny** is both high-yielding and also capable of producing seed/ grain.

> - **DMH-11** is claimed to have shown an average **28% yield increase** over Varuna in contained field trials carried out by the Indian Council of Agricultural Research (ICAR).

- This system was used to develop **DMH-11** by crossing a popular Indian mustard variety 'Varuna' (the barnase line) with an **East European 'Early Heera-2' mutant (barstar).**
- **BT Cotton:**
  - In order to tackle the bollworm attack that had devastated cotton crops in the past, Bt cotton was introduced which was **jointly developed by the Maharashtra Hybrid Seeds Company (Mahyco) and the US seed company Monsanto**.
  - In 2002, the GEAC approved Bt Cotton for commercial cultivation in 6 states such as Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, and Tamil Nadu. It has to be noted that, Bt cotton is the first and only transgenic crop approved by the GEAC.
- **BT Brinjal:**
  - **Mahyco** jointly developed **Bt Brinjal with the Dharwad University of Agricultural Sciences and the Tamil Nadu Agricultural University**.
  - Even though GEAC 2007 had recommended the commercial release of Bt Brinjal, the initiative was blocked in 2010.

7. GENOME SEQUENCING AND THE GENOME INDIA PROJECT

CONTEXT

The **Department of Biotechnology (DBT)** recently said that the exercise to sequence 10,000 Indian human genomes and create a database under the Centre-backed Genome India Project is about two-thirds complete.

What is the human genome?

- The human genome is the entire set of **deoxyribonucleic acid (DNA)** residing in the nucleus of every cell of each human body.

- It carries the complete genetic information responsible for the development and functioning of the organism.
- **Base:** The DNA consists of a double-stranded molecule built up by four bases –
  - adenine (A)
  - cytosine (C)
  - guanine (G)
  - thymine (T)
- Every base on one strand pairs with a complementary base on the other strand (A with T and C with G).
- In all, the genome is made up of approximately 3.05 billion such base pairs.

What is genome sequencing?

- While the sequence or order of base pairs is identical in all humans, there are differences in the genome of every human being that make them unique.
- The process of deciphering the order of base pairs, to decode the genetic fingerprint of a human is called genome sequencing.

- **Human Genome Project:** In 1990, a group of scientists began to work on determining the whole sequence of the human genome under the **Human Genome Project.**
  - The first results of the complete human genome sequence were given in 2003. However, some percentage of repetitive parts were yet to be sequenced.
  - The Human Genome Project released the latest version of the complete human genome in 2023, with a 0.3% error margin.
- **Genome India project:** Genome India Project is a research initiative to gather samples, compile data, conduct research, and create an 'Indian reference genome' grid
  - India's 1.3 billion-strong population consists of over 4,600 population groups, many of which are endogamous. Thus, the Indian population harbours distinct variations, with disease-causing mutations often amplified within some of these groups.
  - Creating a database of Indian genomes allows researchers to learn about genetic variants unique to India's population groups and use that to customise drugs and therapies.

Application of genome sequencing

- Genome sequencing has been used to evaluate rare disorders, preconditions for disorders, and even cancer from the viewpoint of genetics, rather than as diseases of certain organs.
- Nearly 10,000 diseases — including **cystic fibrosis and thalassemia** — are known to be the result of a single gene malfunctioning.

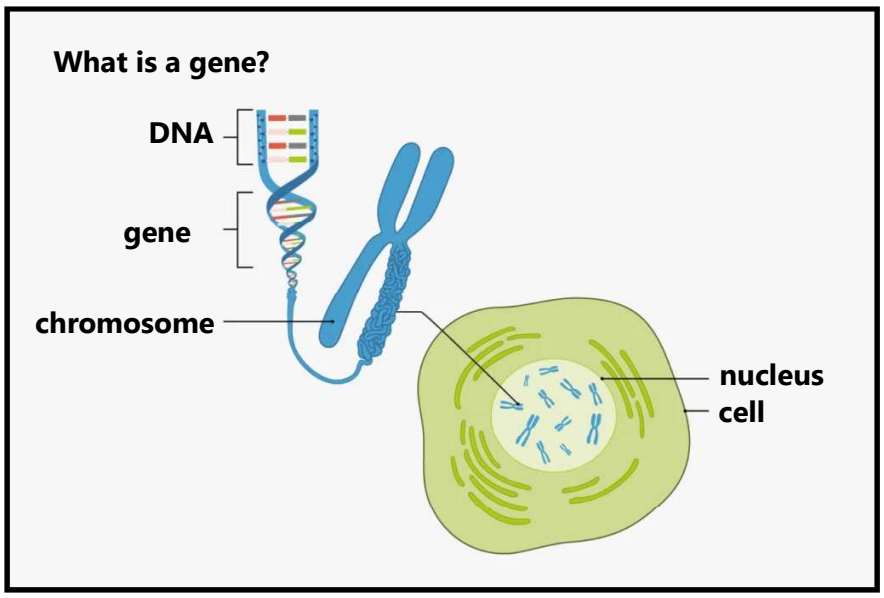
8. UNDERSTANDING A HUMAN PAN-GENOME MAP

CONTEXT

A new study published in the journal Nature describes a **pan-genome reference map** created utilising genomes from **47 anonymous** individuals (**19 men and 28 women**), mostly from Africa but also from the **Caribbean, Americas, East Asia, and Europe**.

What is a genome?

- The genome is the **blueprint of life**, a collection of all the genes and regions between the genes contained in our **23 pairs of chromosomes**.
- Each chromosome is a contiguous stretch of **DNA string** composed of millions of individual **building blocks called nucleotides or bases**.



- **Genome sequencing is the method used to determine the precise order of the four letters and how they are arranged in chromosomes**.
- Sequencing individual genomes **helps us understand human diversity at the genetic level and how prone we are to certain diseases**.
- To circumvent this, one can have a collective identity card, such as a **single genome identity card** for everyone living in a region.

What is a reference genome?

- The making of the first reference **genome in 2001** was a scientific breakthrough, helping scientists discover thousands of genes linked to various diseases and design novel diagnostic tests.
- However, the reference genome was 92% complete and contained many gaps and errors.
- Since then, the reference genome map has been refined and improved to have complete **end-to-end sequences of all 23 human chromosomes**.
- However, the finished **reference genome map does not represent all of human diversity**.
- This new study published in Nature changes this, describing the making of the pangenome map, the genetic diversity among the 47 individuals, and the computational methods developed to build the **map and represent differences in those genomes**.

What is a pangenome map?

- The pangenome is a **graph of each chromosome**, with nodes where sequences of all 47 individuals converge and internodes representing genetic variations.
- To create complete and contiguous chromosome maps, researchers used long-read **DNA sequencing technologies**, which produce strings of contiguous DNA strands of tens of thousands of nucleotides long.
- This **helps assemble the sequences with minimum errors** and **read through repetitive regions of the chromosomes**.

Why is a pangenome map important?

- The human genome consists of 3.2 billion individual nucleotides, with a 0.4% difference between any two individuals.
- A complete and **error-free pangenome map will help us understand these differences and explain human diversity better**.
- It has added nearly 119 million new letters and aided the discovery of 150 new genes linked to autism.
- Future **pangenome maps** that **include high quality genomes** from Indians **will shed light on disease prevalence, help discover new genes for rare diseases, design better diagnostic methods, and help discover novel drugs**.

9. MITOCHONDRIAL DONATION TREATMENT (MDT)

CONTEXT

A groundbreaking **IVF** procedure has been successfully performed in the United Kingdom, resulting in the birth of the first baby with genetic material from three persons, with the help of **Mitochondrial donation treatment (MDT).**

What is Mitochondrial Donation Treatment (MDT)?

Mitochondrial diseases affect 1 in 5,000 people globally and can cause severe health problems, including muscle weakness, organ failure, and neurological disorders.

- Mitochondrial donation treatment (MDT) is a medical procedure aimed at preventing **inherited diseases** caused by **mutations** in the **mitochondrial DNA (mtDNA).**
- The treatment involves **replacing the faulty mitochondria** in a woman's egg or embryo with **healthy mitochondria** from a donor.
- Inherited mutations in mtDNA can cause mitochondrial disease, which is incurable and can lead to severe health problems.

Mitochondria are the powerhouse of the cell and are responsible for producing energy. They have their own DNA, separate from the nuclear DNA that determines an individual's physical traits.

How defects occur in Mitochondria?

- Mitochondria are basically the powerhouses of the cells. They generate energy, and thus are also responsible for cell function in the human body.
- They have their own DNA, which is separate from the DNA in the cell's nucleus, and mutations in mitochondrial DNA can lead to a range of serious health conditions.
- Certain defects might occur impacting the way the mitochondria produces energy for the cells (especially in the 'energy-hungry' tissues of the brain, nerves, muscles, kidneys, heart, liver), and thereby impacting cell function.
- The diseases that arise out of such mitochondrial mutations are called **mitochondrial diseases**.

- Mitochondrial diseases are only passed on by the mother
- Some estimates put the incidence of mitochondrial diseases as one in 5,000 people.

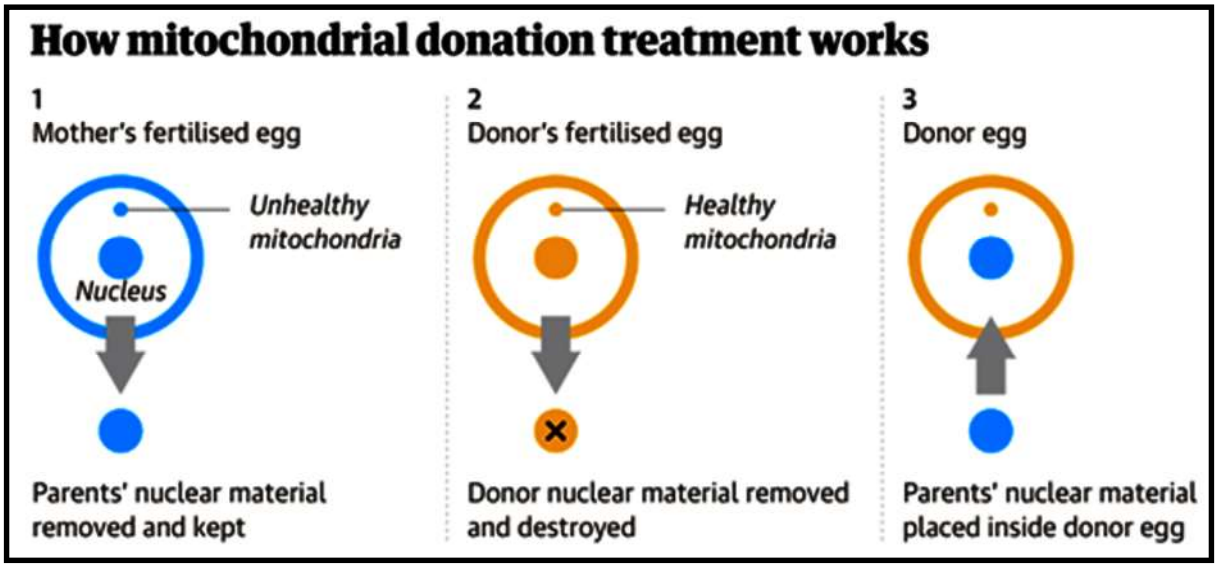
- **Impact:** When the mitochondria are impaired and do not produce sufficient energy, it affects how organs function, leading to a broad assortment of symptoms across the body, including brain damage, organ failure and muscle wastage.

How Does MDT Work?

MDT involves the use of **in vitro fertilization (IVF)** to create an embryo with genetic material from three people: the mother, the father, and the mitochondrial donor. The process can be done in two ways:

The **genetic material** from the donated egg comprises less than **1 percent** of the child's genetics

- **Pronuclear transfer**: This involves transferring the nucleus of the mother's fertilized egg or embryo into the cytoplasm of a donor egg or embryo with healthy mitochondria. The resulting embryo has nuclear DNA from the mother and father and healthy mtDNA from the donor.
- **Maternal spindle transfer:** This involves transferring the nucleus of the mother's egg into a donor egg with healthy mitochondria before fertilization. The resulting embryo has nuclear DNA from the mother and father and healthy mtDNA from the donor.



What is the legal Status of MDT?

- The **United Kingdom was the first country to legalize MDT in 2015.**
- The law allows the procedure to be used in cases where there is a high risk of transmitting a severe mitochondrial disease. The first baby born using MDT in the UK was in 2016.
- Since then, a few other countries, including the **United States,** have also approved the use of MDT under strict regulations.

Status in India

- In India, the MDT procedure is not currently allowed.
- However, the **Indian Council of Medical Research (ICMR)** has issued draft guidelines for MDT and is seeking public comments.

10. METAGENOME SEQUENCING

CONTEXT

In order to get a breakthrough in the definitive identification of **SARS-CoV-2**, Scientists didn't go the more time-consuming microbiology route; instead, and in a break from tradition, they were directly subjected to genome-sequencing and bioinformatic analysis, which helped the scientists quickly identify the virus. This new approach is called **metagenomics**.

What is Metagenomics?

- Metagenomics is a field of molecular biology and genomics
- It refers to the application of sequencing techniques to analyse the totality of the genomic material (DNA or RNA) present in a sample.
- **Metagenomics** uses **gene sequencing** to discover proteins in samples from environments across Earth, microbes living in the soil, in extreme environments like hydrothermal vents, deep in the oceans and in our guts and on the skin.
- A vast number of proteins, beyond those catalogued in well-studied organisms, exist in the natural world.

What are its major applications?

- **Microbiome Research:** Understanding the composition and functional roles of microbial communities in various environments, such as the human gut, soil, oceans, and plants. This knowledge has implications for health, agriculture, and ecology.
- **Biotechnology:** Identifying novel enzymes, pathways, and metabolic functions from environmental samples, which can be used for industrial processes, such as bioremediation, biofuel production, and the synthesis of valuable chemicals.

- **Disease Diagnosis:** Investigating the role of microbial communities in human health and disease. Metagenomic analysis can help identify potential pathogens, study the human microbiome, and understand the impact of microbial dysbiosis on various health conditions.
- **Environmental Monitoring:** Assessing the impact of pollution, climate change, and other environmental factors on microbial ecosystems. Metagenomics can provide insights into ecosystem health and aid in conservation efforts.
- **Pharmaceutical Discovery:** Exploring natural products and bioactive compounds produced by diverse microorganisms in the environment, which may have potential applications in drug development.
- **Evolutionary Studies:** Examining the evolutionary relationships between microorganisms and tracing the evolution of specific genes or functions within microbial communities.
- **Agriculture and Food Safety**: Analyzing the microbiota of crops, livestock, and food products to improve agricultural practices, enhance crop yield, and ensure food safety.
- **Bioprospecting:** Identifying novel species and genetic elements with unique properties that can be used for various purposes, including biotechnology, medicine, and industrial processes.

How significant is the new technique?

- It allows researchers to analyze the collective genomes of diverse microorganisms within a given sample, providing insights into the genetic diversity, functional capabilities, and interactions of these microbial communities.
- Metagenomics is particularly valuable for understanding the microbial composition of complex ecosystems and has applications in various fields, including ecology, biotechnology, and medicine.

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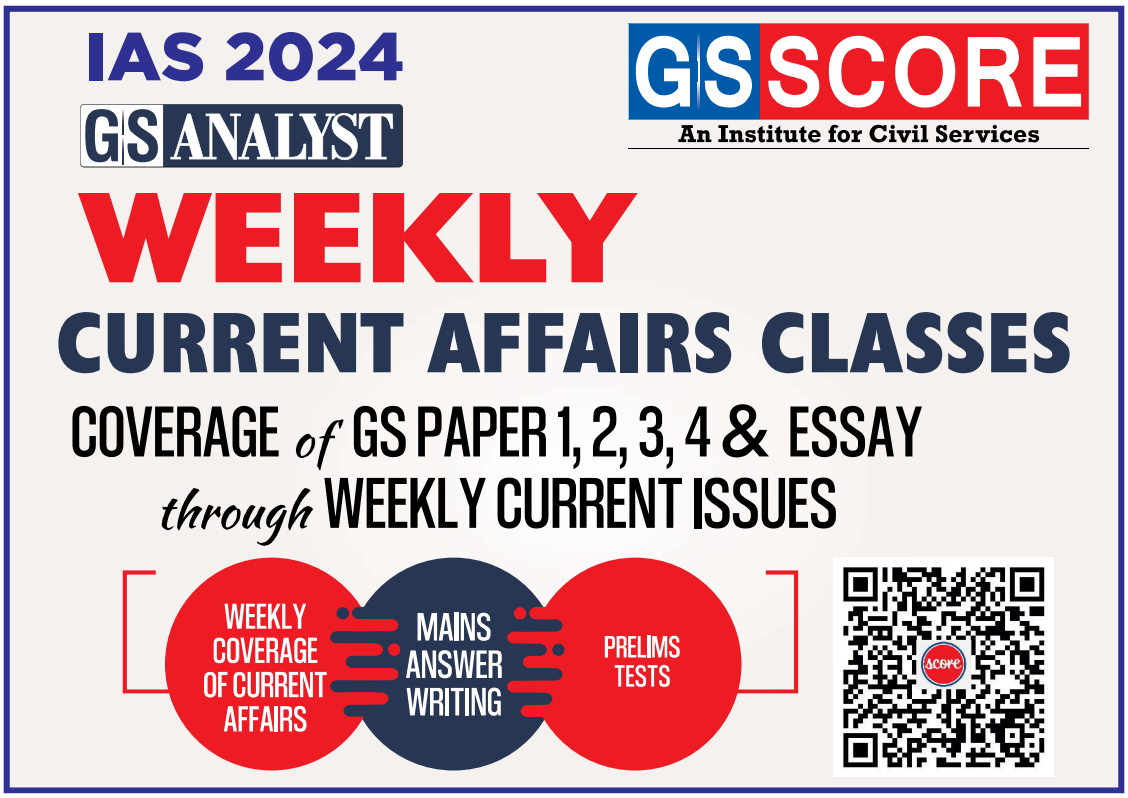

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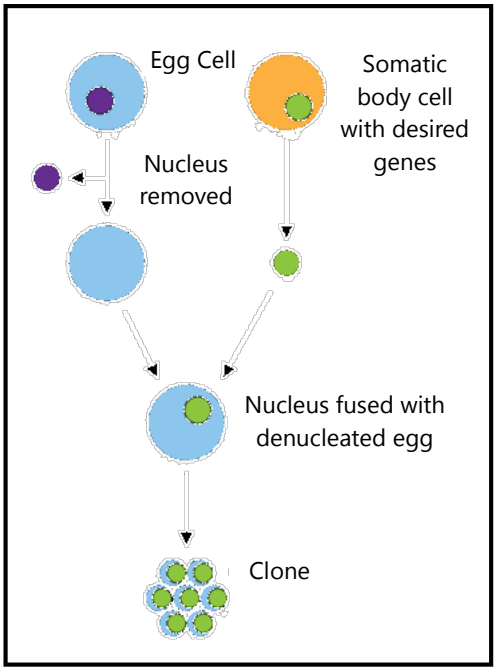
Biotechnology & Cells

1. CLONING

CONTEXT

India's first cloned Gir cow **Ganga** was born at **National Dairy Research Institute** in Karnal, Haryana.

What is Cloning?

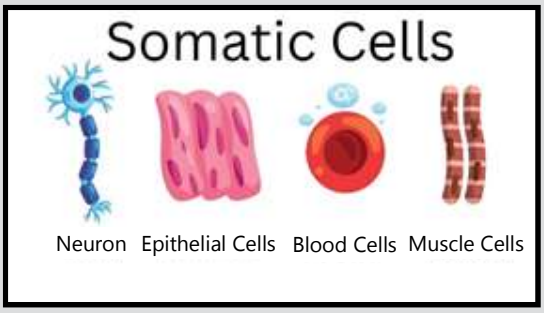


- **C**loning is a technique scientists use to make exact genetic copies of living things. Genes, cells, tissues, and even whole animals can all be cloned
- Types of cloning:
  - **Therapeutic:** In therapeutic cloning, the aim is to clone cells that make particular organs or types of tissue
  - **Reproductive:** In this we actually reproduce not organ but entire being (donor) from where we got genetic information

Methods:

- **Natural:** This happens naturally when one embryo spontaneously divides into two or more embryos, thus creating identical twins or, sometimes, triplets or even more
- **Artificial:** An existing embryo is mechanically divided into two or more embryos that are then allowed to develop naturally
- **Artificial and Donor:** Through use of somatic cell of Donor.

Role of somatic cells:



- Somatic cells are all the cells that make up an organism, but that are not sperm or egg cells.
- Sperm and egg cells contain only one set of chromosomes, and when they join during fertilization, the mother's chromosomes merge with the father's.
- Somatic cells, on the other hand, already contain two full sets of chromosomes.
- To make a clone, scientists transfer the DNA from an animal's somatic cell into an egg cell that has had its nucleus and DNA removed. The egg develops into an embryo that contains the same genes as the cell donor. Then the embryo is implanted into an adult female's uterus to grow.

2. CHIMERIC ANTIGEN RECEPTOR T (CAR-T) CELL THERAPY

CONTEXT

India's first indigenously developed **Chimeric Antigen Receptor (CAR)-T Cell T therapy** for specific types of cancer patients has shown promising results and could be the safest therapy in this category so far.

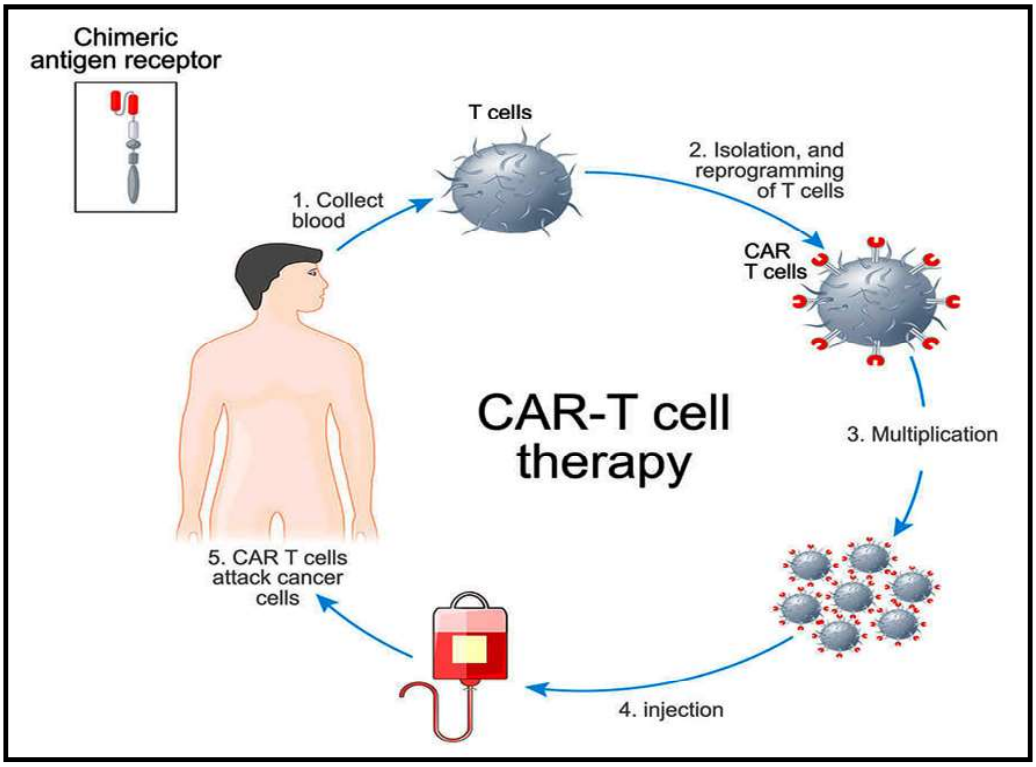
What is Chimeric Antigen Receptor (CAR)-T Cell T therapy?

- Chimeric antigen receptor T cells are cells that are **genetically engineered** (changed) in a laboratory.
- They have a **new receptor** so they can bind to cancer cells and kill them. Different types of cancer have different antigens.
- Each kind of CAR T cell therapy is made to fight a specific kind of cancer antigen.
- T cells are taken from a patient's blood.
- Then the gene for a special receptor that binds to a certain protein on the patient's cancer cells is added to the T cells in the laboratory.
- The special receptor is called a chimeric antigen receptor (CAR).

About T-Cells

- **T-cells** are a type of white blood cell called lymphocytes. They help your immune system fight germs and protect you from disease. There are two main types.
  - **Cytotoxic T-cells** destroy infected cells.
  - **Helper T-cells** send signals that direct other immune cells to fight infection.

- Large numbers of the CAR T cells are grown in the laboratory and given to the patient by infusion.
- CAR T-cell therapy is used to treat certain blood cancers and it is being studied in the treatment of other types of cancer. Also called chimeric antigen receptor T-cell therapy.



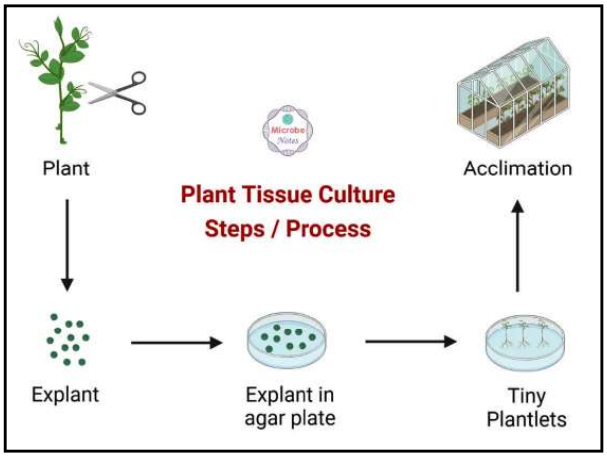
3. TISSUE CULTURE PLANTS

CONTEXT

The **Agricultural and Processed Food Products Export Development Authority (APEDA)** conducted a webinar on **"Export Promotion of Tissue Culture Plants such as Foliage, Live Plants, Cut Flowers, and Planting Material".**

- The **Department of Biotechnology (DBT)** accredited **tissue culture** laboratories spread across India participated in the Webinar.

What is plant tissue culture?



- Plant tissue culture is the **in vitro aseptic culture** of **cells, tissues, organs, or whole plant** under a nutrient culture medium of known composition and environmental conditions.
- It is culturing plant seeds, organs, explants, tissues, cells, or protoplasts on a chemically defined synthetic nutrient media under sterile and controlled conditions of light, temperature, and humidity.
- **Advantages of plant tissue culture:**
  - Quickly produce mature plants

- Allows them to be moved with greatly reduced chances of transmitting diseases, pests, and pathogens
- Storage of genetic plant material to safeguard native plant species

India's exports of tissue culture plants:

- In 2020-2021, India's exports of tissue culture plants stood at US USD 17.17 million, with the Netherlands accounting for around 50 per cent of the shipments.
- The top ten countries importing tissue culture plants from India are the **Netherlands, USA, Italy, Australia, Canada, Japan, Kenya, Senegal, Ethiopia and Nepal.**

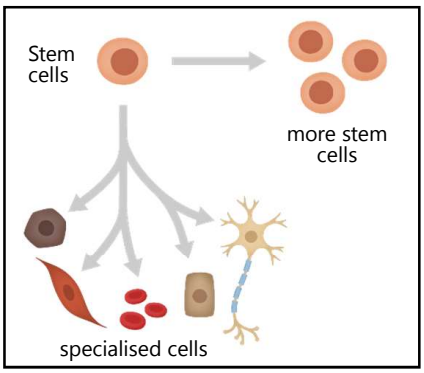
4. STEM CELLS

CONTEXT

Scientists from the University of Cambridge have achieved the rare feat of creating the world's first synthetic embryo that has a brain and a beating heart.

- **Concept involved:** The embryo was created using the **stem cells** of the mouse instead of the normal process of fusing sperm and egg cells.

What are stem cells?



- A stem cell is a cell with the unique ability to develop into specialized cell types in the body.
- These cells provide new cells for the body as it grows, and replace specialized cells that are damaged or lost.
- In the future, they will be used to replace cells and tissues that have been damaged or lost due to disease.
- Our body is made up of numerous types of cells.
- Most cells are specialized for particular functions, like the red blood cells that carry oxygen in our bodies through the blood, but they are unable to divide.
- All stem cells regardless of their source have three general properties:
  - They are capable of dividing and renewing themselves for long periods
  - They are unspecialized
  - They can give rise to specialized cell types

Stem cell therapy:

- Stem cell therapy, also known as regenerative medicine, promotes the repair response of diseased, dysfunctional, or injured tissue using stem cells or their derivatives.
- Stem cells may be one of the ways of generating new cells that can be transplanted into the body to replace the damaged or lost cells.

5. CELL-CULTIVATED MEAT AND ADVANTAGES

CONTEXT

Recently, **two California based companies** were cleared to make and sell cell cultivated chicken. As a concept, it is being hailed by stakeholders as a major step towards **reducing carbon emissions** associated with the food industry worldwide.

What is cell-Cultivated chicken?

- Cell-Cultivated meat is also called **as 'Cultured meat'.**
- **Process of Isolation-** It involves isolation of the cells that make up the meat (the meat that we consume), and putting them in a setting where they have all the resources they need to grow.
- **Processed with additives-** Once there are enough cultivated cells, they are collected and processed with additives to improve texture.

India's Meat Market:

- According to a research, meat production in India is estimated at 6.3 million tons annually and is **ranked 5th** in the world in terms of production volume.
- India is responsible for **3% of the total meat production in the world**.
- The nation has the **world's largest population of livestock** at about 515 million.

Need for Lab-grown meat in India:

- **Higher consumption**: According to data from the **National Family Health Survey 5** by India's **Ministry of Health and Family Welfare**, close to 77 percent of India's population eats fish, chicken and other types of meat.
- The survey also discovered that 83 percent of men and 71 percent of women are non-vegetarians.
- **Environmental hazards:** According to a joint report by the **Vasudha and Shakti foundations,** Indian livestock is responsible for the annual emission of over **200 million tons of CO2 into the atmosphere**.
- **Less resource consumption**: Lab-grown meat enterprises use up to **95 percent less land and 78 percent less water** when renewable energy is used in production than conventional meat.
- **For making Nutrition food affordable**: As per the World Bank, in 2019, 10.2 percent of Indians were projected to have been living below the **international poverty level.**
- Hence, it is believed that the **cost of cultivated meat** will most likely decline when production scales up.

Challenges to be addressed:

- **Consumer acceptance**-Perfectly substituting animal meat with alternative meat requires it to match the original in taste, texture and appearance.

- **Cost Analysis**- The cost of cell cultivated meat is expected to remain high in the near future.
- **Availability of conducive environment for cultivation-** For cultivation, researchers require high quality cells, a suitable growth medium in which the cells can be cultured, plus other resources required to maintain the quality of the final product.

Government Interventions:

- **GFI India's National Mission for Smart Protein**, the group has partnered with the Institute of Chemical Technology (ICT) Mumbai to establish the world's first government research **Centre for the development of cultivated meat.**
- GFI India has also partnered with **ICAR-Central Institute of Fisheries Education (Mumbai)** with the aim of establishing India's '**first Smart Protein Innovation Hub on Cultivated Seafood'**.

6. 'MISMATCH REPAIR DEFICIENT' CANCER

CONTEXT

Twelve patients in the United States were completely cured of **rectal cancer** without requiring any **surgery or chemotherapy** found in a medical trial.

What is Rectal Cancer?

- Rectal cancer is cancer that begins in the rectum. The rectum is the last several inches of the **large intestine.**
- It starts at the end of the final segment of colon and ends when it reaches the short, narrow passage leading to the anus.
- While rectal cancer's treatments are quite different. This is mainly because the rectum sits in a tight space, barely separated from other organs and structures.
- The tight space can make surgery to remove rectal cancer complex.
- **Signs and symptoms of rectal cancer include**:
  - A change in bowel habits, such as diarrhea, constipation or more-frequent bowel movements
  - Dark maroon or bright red blood in stool
  - Narrow stool
  - A feeling that your bowel doesn't empty completely
  - Abdominal pain
  - Unexplained weight loss
  - Weakness or fatigue

What is PD1 Therapy?

- PD1 is a type of protein that regulates certain functions of the immune system, including by

suppressing **T cell activity**, and PD1 blockade therapy looks to release the T cells from this suppression.

- T-cells are the **White Blood cells (WBCs)**. They are critical for developing immunity towards common pathogens or antigens.
- Although the therapy is usually used for cancers that have metastasised (spread to locations other than where the cancer formed), it is now recommended for all mismatch repair deficient cancers as they result in quicker improvement and lesser toxicity as compared to traditional chemo and radiotherapy.
- Eliminating other treatments can improve a patient's quality of life by preserving fertility, sexual health, and bladder and bowel functions.

What are monoclonal antibodies?

- Monoclonal antibodies are laboratory-produced molecules engineered to serve as substitute antibodies that can restore, enhance, modify or mimic the immune system's attack on cells that aren't wanted, such as cancer cells.

Mismatch repair deficient cancer:

- It is most common among colorectal, gastrointestinal, and endometrial cancers.
- Patients suffering from this condition **lack the genes to correct typos in the DNA** that occur naturally while cells make copies.
- The anomalies in the DNA result in cancerous growths in patients.

7. EVOLUTION OF PROKARYOTES TO EUKARYOTES

CONTEXT

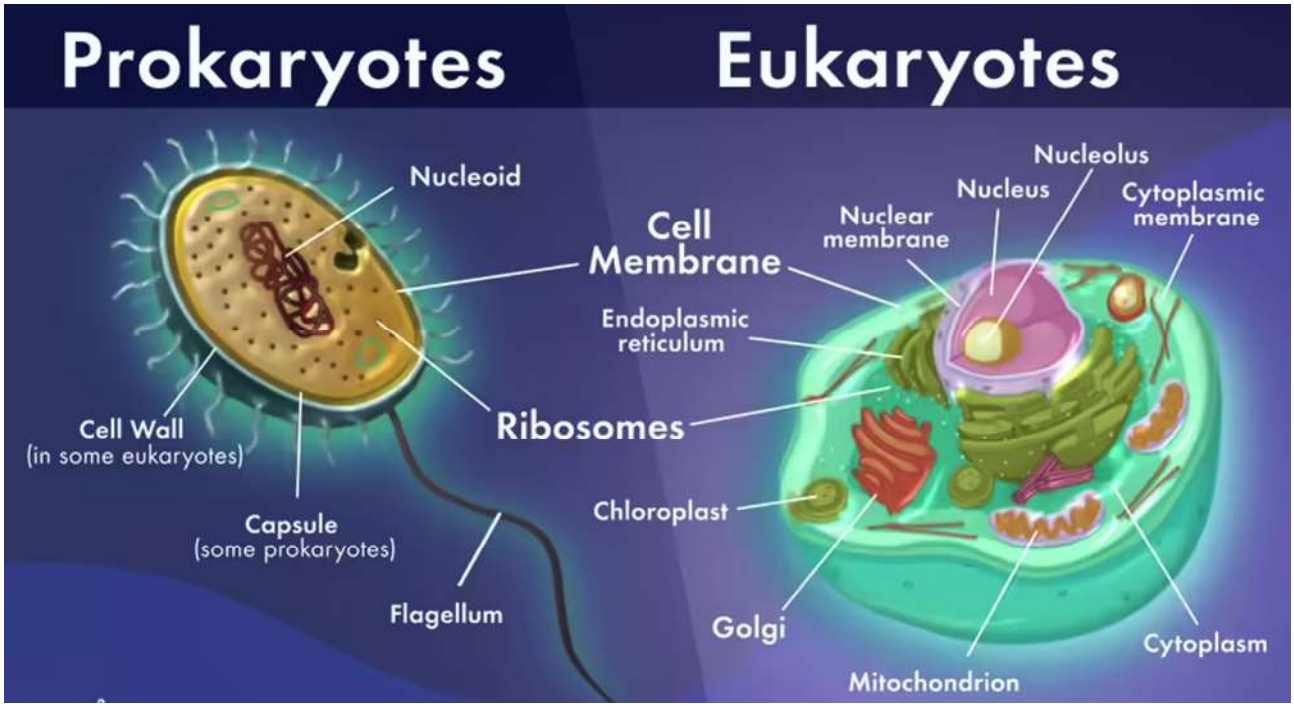
Recently, it was found that evolution of eukaryotes from prokaryotes can answer the question of how complex cells with nuclei and organelles emerged.

- The **existing 'theory of endosymbiosis'** suggests that eukaryotes evolved from a symbiotic relationship between an ancient **archaeon (a primitive group of microorganisms that thrive in extreme habitats)** and a bacterium.

What are Prokaryotes and Eukaryotes?

- **Prokaryotes:** They are organisms that lack a true nucleus and membrane-bound organelles.
  - Their genetic material, typically a circular DNA molecule, is present in the cytoplasm without being enclosed within a nuclear membrane.
  - Prokaryotes include bacteria and archaeon.
  - Key features include **small, simple cells without a nucleus or organelles.**

- **Eukaryotes:** are organisms that have cells containing a well-defined nucleus enclosed within a membrane.
  - Eukaryotic cells have a variety of membrane-bound organelles such as mitochondria, endoplasmic reticulum, Golgi apparatus, and a complex network of internal membranes**.**



About the Evolution:

- **Endosymbiosis** is a process where "**one organism lives inside another and both benefit from the relationship."**
- The endosymbiotic theory suggests that eukaryotes evolved from a **small archaeon** engulfing a bacterium.
- The archaeon protected the bacterium and provided a stable environment, while the bacterium supplied energy to the archaeon.
- Over time, they became dependent on each other and formed a new type of cell called a eukaryote.
- The engulfed bacterium became the mitochondrion, which produces energy for the cell.
- In plants, another endosymbiotic event occurred with a cyanobacterium becoming the chloroplast, responsible for photosynthesis.
- This symbiotic relationship allowed eukaryotes to grow larger, become more complex, and adapt to different environments.

Significance of the evolution:

- Mitochondria in **eukaryotic cells** and chloroplasts in plant cells have evolved from **free-living bacteria**.
- These organisms are found in a geological formation where **geothermally heated water** is forced out of a ridge in the Atlantic Ocean floor at a depth of 2400 meters below sea level.

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3

Biotechnology & Government Initiatives

1. SYNTHETIC BIOLOGY

CONTEXT

The Centre is working on a national policy on **synthetic biology**, an emerging science that deals with engineering life forms for a wide range of applications from making designer medicines to foods.

Background

- As part of the **12th Five-Year Plan**, India had set up a **task force** on systems biology and synthetic biology research in 2011.
- This body underlined the **potential benefits** from synthetic biotechnology in biofuels, bioremediation, biosensors, food and health and made a strong case for a push for the technology.
- It highlighted that India could be a world leader as a protector and supporter of "**open-source biological platforms**".

What is Synthetic Biology?

- Synthetic biology is the field of research in which the main objective is to create **fully operational** biological systems from the **smallest constituent parts** possible, including DNA, proteins, and other organic molecules.
- The synthetic systems created may be used to generate products ranging from ethanol and **drugs** to complete **synthetic organisms** such as complex bacteria that can digest and neutralize toxic chemicals.
- Ideally, these customized synthetic biological systems and organisms would be much **safer** and less complicated than approaches based on the manipulation of naturally occurring biological entities.

Applications of synthetic biology:

- **Redesigning organisms** so that they produce a substance, such as a medicine or fuel, or gain a

new ability, such as sensing something in the environment, are common goals of synthetic biology projects.

- Some examples of what scientists are producing with synthetic biology are:

Application in pharmaceuticals:

- For instance, researchers have been working on the synthetic manufacture of the **antimalarial drug artemisinin**, which is produced naturally in the sweet wormwood plant, a slow-growing species.
- Scientists have been trying to create new forms of bacteria that **can destroy tumors**.
- Department of Defense has experimented with the creation of **biological computers**, and other military scientists are trying to engineer proteins and gene products from scratch that will act as **targeted vaccines or cures**.

Application in Biofuels:

- In the area of biofuels, scientists at numerous companies are trying to create **microbes** that can **break down dense feedstocks** to produce biofuels.
- Modify the genes of microbes to **secrete oil**. If successfully scaled up for commercial production, these organisms could serve as valuable sources of **renewable energy**.

Other Applications:

- Microorganisms harnessed for **bioremediation** to clean pollutants from our water, soil and air.
- **Rice modified** to produce beta-carotene, a nutrient usually associated with carrots that prevents vitamin A deficiency.
- **Yeast engineered** to produce rose oil as an eco-friendly and sustainable substitute for real roses that perfumers use to make luxury scents.

2. INDIAN BIOLOGICAL DATA CENTER

CONTEXT

The Government launched **India's first national repository** for life science data, the **Indian Biological Data Centre (IBDC)** at Faridabad, Haryana.

About:

- The 'Indian Biological Data Centre (IBDC)' is the **first national repository** for life science data in India.
- **Purpose:** deposition, storage, annotation and sharing of biological data.
- The data center is supported by the Government of India (GOI) through the **Department of Biotechnology (DBT).**

- It has a data storage capacity of about **4 petabytes** and houses the '**Brahm' High-Performance Computing (HPC) facility.**
- IBDC has started **nucleotide data submission services** via two data portals namely:
  - Indian Nucleotide Data Archive (INDA)
  - Indian Nucleotide Data Archive -Controlled Access (INDA-CA)

3. BIOTECH-PRIDE GUIDELINES

CONTEXT

Biotech-PRIDE (Promotion of Research and Innovation through Data Exchange) Guidelines was released by the **Department of Biotechnology (DBT), Ministry of Science and Technolog**y.

Key-highlights of the guidelines

- Biotech-PRIDE guideline aims at providing a well-defined framework and guiding principle to facilitate and enable sharing and exchange of **biological knowledge, information and data.**
  - This exchange will promote research and innovation in different research groups across the country.
- These guidelines will ensure data sharing benefits like **maximizing use, avoiding duplication, maximized integration, ownership information, better decision-making and equity of access.**
- **Implementing agency:** They will be implemented through the **Indian Biological Data Centre (IBDC)** at Regional Centre for Biotechnology supported by the **Department of Biotechnology.**
- Other existing datasets/ data centres will be bridged to this IBDC which will be **called Bio-Grid.**

Bio-Grid

- This Bio-Grid will be a **National Repository for biological knowledge**, information and data.
- It is going to be responsible for enabling its exchange, developing measures for safety, standards and quality for datasets and establishing detailed modalities for accessing data.

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4

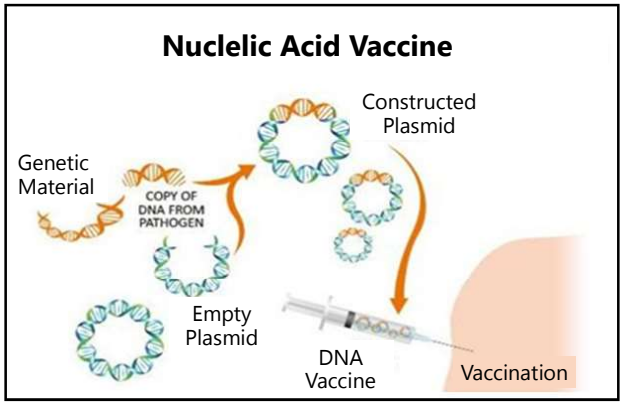
Vaccines

1. NUCLEIC ACID VACCINES

CONTEXT

The novel Nucleic acid-based vaccine candidate of the Pune-based Gennova Biopharmaceuticals was approved for funding as early as July 2022 by the **Department of Biotechnology (DBT).**

What is Nucleic acid-based vaccines?



- Nucleic acid vaccines use **genetic material** from a **disease-causing virus** or **bacterium (a pathogen**) to stimulate an **immune response** against it.
- Depending on the vaccine, the genetic material could be **DNA or RNA**; in both cases it provides the instructions for making a specific protein from the **pathogen**, which the immune system will recognise as **foreign (an antigen).**
- Once inserted into host cells, this genetic material is read by the cell's own protein-making machinery and used to manufacture antigens, which then trigger an immune response.
- **Advantages**: simplicity of the vector, the ease of delivery, the duration of expression, and, to date, the lack of evidence of integration.

Other COVID-19 vaccine types

- **Whole virus:** Whole virus vaccines use a weakened or deactivated version of the disease-causing virus to trigger protective immunity against it.

- **Viral vector:** Viral vector-based vaccines use a harmless virus to smuggle the instructions for making antigens from the disease-causing virus into cells, triggering protective immunity against it.
- **Protein subunit:** Protein subunit vaccines use fragments of protein from the disease-causing virus to trigger protective immunity against it.

2. INDIA'S FIRST MRNA BASED OMICRON-SPECIFIC BOOSTER VACCINE

CONTEXT

India's first indigenous **mRNA vaccine** for the Omicron variant, **GEMCOVAC-OM**, developed by Pune-based Gennova Biopharmaceuticals Ltd, was approved under emergency use guidelines by the **Drug Controller General of India.**

About

- The vaccine is the first booster Covid-19 vaccine developed in India against the highly transmissible Omicron variant
- The vaccine is a **lyophilised (freeze dried) vaccine**, stable at two to eight degrees Centigrade.
- The vaccines could be administered into the skin via a **"needle-free" PharmaJet system.**

What are mRNA vaccines?

- The mRNA vaccines use mRNA's function as a protein information carrier to prompt the body to make specific proteins.
  - In the case of COVID-19 vaccines, the mRNA instructs the cells to produce the spike protein found on the outside of the SARS-CoV-2 virus.
- When the body's immune system detects these foreign proteins, it produces antibodies and other immune cells to fight what looks like an infection.
- Then, if the immune system encounters that protein again in the future, it's primed to mount a rapid response.

About messenger RNA (mRNA)

- Messenger RNA (mRNA) is a molecule that contains the instructions or recipe that directs the cells to make a protein using its natural machinery.

3. ASSISTED REPRODUCTIVE TECHNOLOGY

CONTEXT

Lok Sabha passed the **Assisted Reproductive Technology Regulation Bill, 2020**, which makes provisions for the safe and ethical practice of assisted reproductive technology (ART) services in the country.

Need for the initiative:

- The growth of ART clinics in India is among the highest in the world, and these are a key part of medical tourism.
  - These offer gamete donation, **intrauterine insemination, in-vitrofertilisation, intracytoplasmic sperm injection, and pre-implantation genetic diagnostic**. India does not have standard protocols of ART clinics yet.

Key-highlights of the Bill

- Assisted Reproductive Technology Regulation Bill, 2020 seeks to provide for the regulation of Assisted Reproductive Technology services in the country.
- **What is ART?** The Bill defines ART to include all techniques that seek to obtain a pregnancy by handling the sperm or the oocyte (immature egg cell) outside the human body and transferring the gamete or the embryo into the reproductive system of a woman.
- **Examples** of ART services include
  - **gamete (sperm or oocyte) donation**
  - **in-vitro-fertilisation (fertilising an egg in the lab)**
  - **gestational surrogacy (the child is not biologically related to surrogate mother)**
- ART services will be provided through:
  - ART clinics, which offer ART related treatments and procedures
  - ART banks, which store and supply gametes

ART bank is an organisation set up to **supply sperm or semen, oocytes, or oocyte donors** to ART clinics or their patients.

What are the other safeguards?

- **NATIONAL BOARD**: It will advise the Centre on policy matters. It will review and monitor rules and regulations, and recommend any changes.
- **NATIONAL REGISTRY**: It will have a central database on all clinics and banks in the country, including nature and types of services provided, and the outcome of these services.
- **REGISTRATION AUTHORITY**: It will have the chairperson, who will be an officer above the rank of Joint Secretary in the Health Department.

The registration authority's functions will include:

- To grant, suspend, or cancel the registration of ART centres.
- To enforce the standards and supervise implementation of the law.
- To investigate complaints of any breach of provisions.
- To take legal action against the misuse of ART and initiate independent investigations.
- To recommend to the National and State Boards on modifying the regulation with changes in technology and social conditions.

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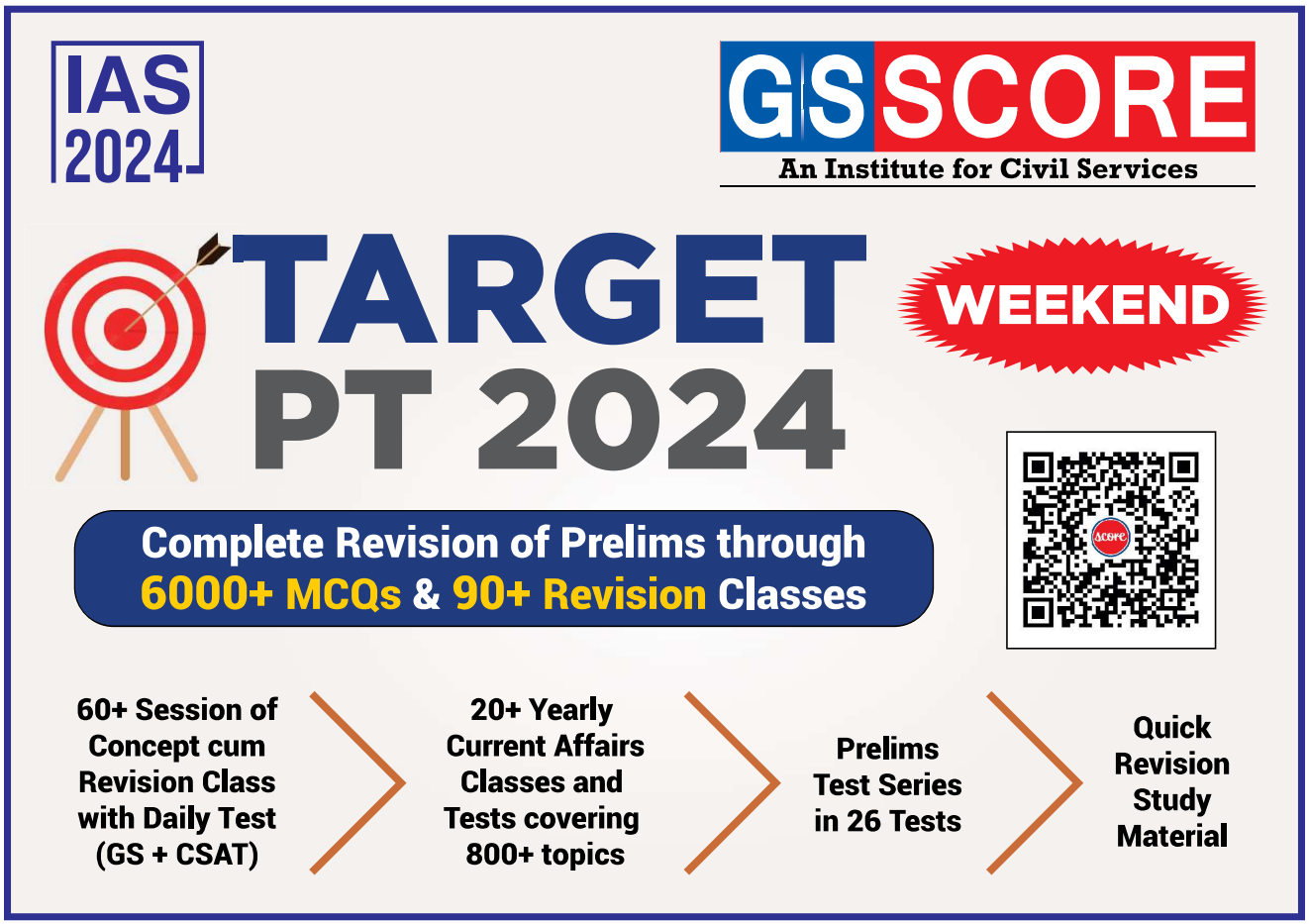


5

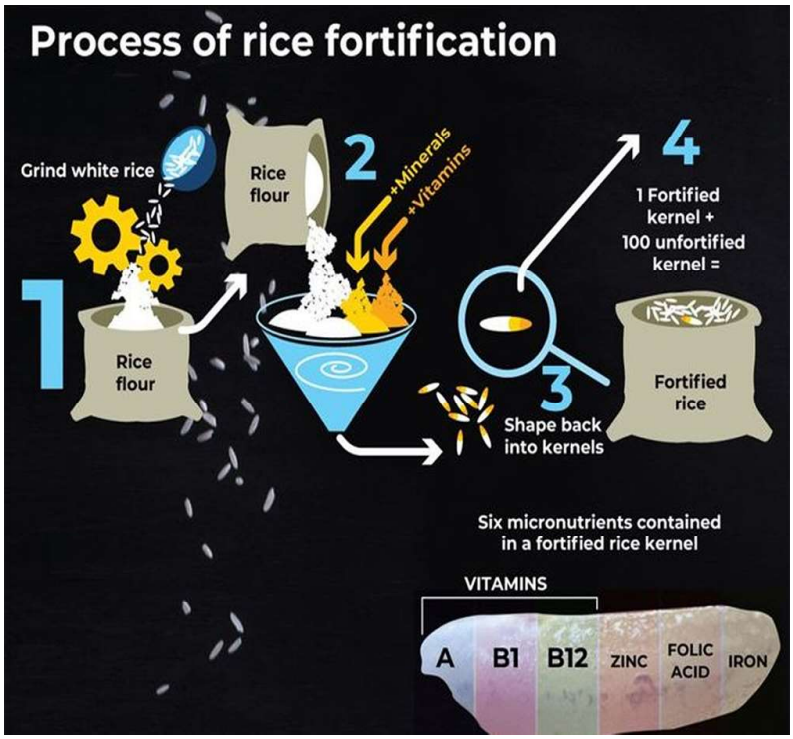
Important Techniques

1. RICE FORTIFICATION AND USES

CONTEXT

The **Cabinet Committee on Economic Affairs** accorded its approval for supply of **fortified rice** throughout the **Targeted Public Distribution System (TPDS)**.

What is rice fortification?



- The Food Safety and Standards Authority of India **(FSSAI)** defines fortification as "**deliberately increasing the content of essential micronutrients in a food so as to improve the nutritional quality of food and to provide public health benefits with minimal risk to health**".
- Various technologies are available to add **micronutrients to regular rice**, such as coating, dusting, and 'extrusion'.
  - The '**Extrusion**' involves the **production of fortified rice kernels (FRKs**) from a mixture using an 'extruder' machine.
  - It is considered to be the best technology for India.
- The fortified rice kernels are blended with regular rice to produce fortified rice.
- Under the Ministry's guidelines, **10 g of FRK must be blended with 1 kg of regular rice.**

- Fortified rice will be **packed in jute bags with the logo ('+F') and the line "Fortified with Iron, Folic Acid, and Vitamin B12".**

Important technologies

- Various technologies are available to add micronutrients to regular rice, such as **coating, dusting, and 'extrusion'.**
- The **'Extrusion'** involves the production of **fortified rice kernels (FRKs)** from a mixture using an '**extruder' machine.** It is considered to be the best technology for India.

Standards for fortification (Ministry of Consumer Affairs, Food and Public Distribution)

- Under the Ministry's guidelines, 10 g of FRK must be blended with 1 kg of regular rice.
- According to FSSAI norms, 1 kg of fortified rice will contain the following:
  - **Iron** (28 mg-42.5 mg)
  - **Folic acid** (75-125 microgram)
  - **Vitamin B-12** (0.75-1.25 microgram)
- Rice may also be fortified with zinc (10 mg-15 mg), vitamin A (500-750 microgram RE), vitamin B-1 (1 mg-1.5 mg), vitamin B-2 (1.25 mg-1.75 mg), vitamin B-3 (12.5 mg-20 mg) and vitamin B-6 (1.5 mg-2.5 mg) per kg

2. ADDITIVE MANUFACTURING

CONTEXT

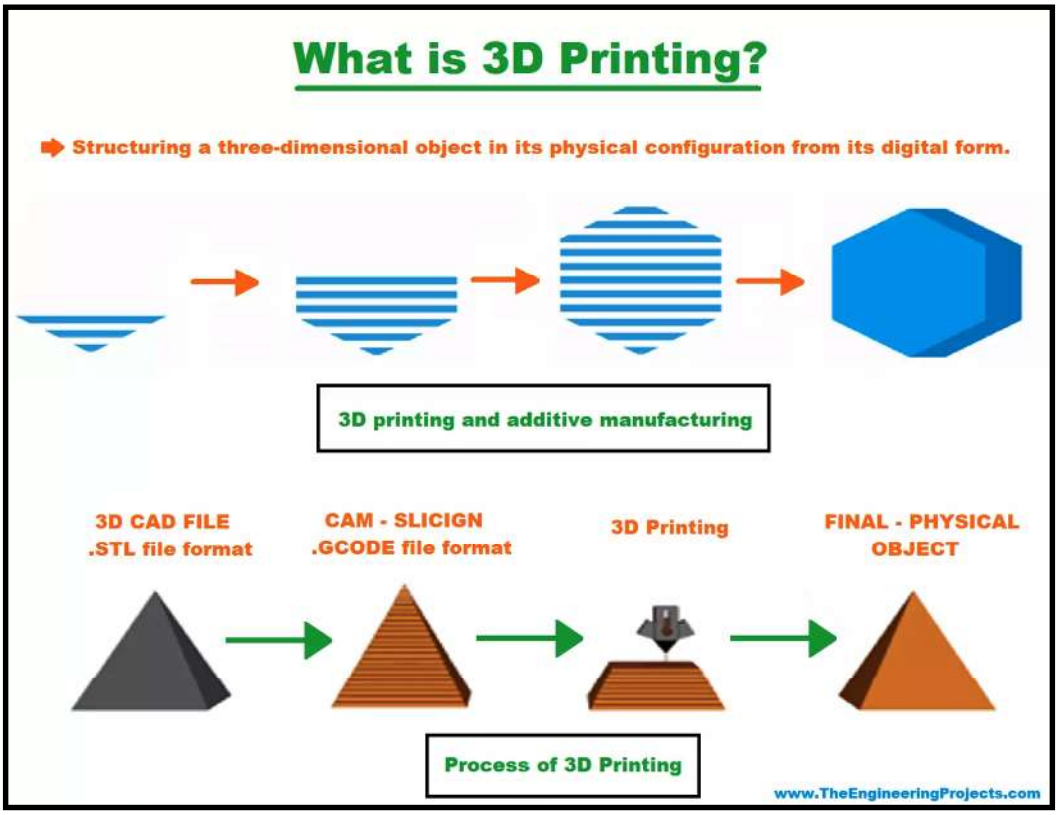
The **Ministry of Electronics and Information Technology (MeitY)** aims to increase India's share in global additive manufacturing to 5 per cent within the next three years.

Additive manufacturing technology or **3D printing** is a type of technology that uses successive layers of material to create 3D objects.

About 3D Printing:

- 3D printing or additive manufacturing uses **computer-aided designing** to make prototypes or working models of objects by laying down successive layers of materials such as plastic, resin, thermoplastic, metal, fiber or ceramic.
- With the help of software, the model to be printed is first developed by the computer, which then gives instructions to the 3D printer.
- This technology makes use of **CAD (Computer-Aided Design)** or 3D object scanners to take precise measurements of the product to be custom designed.

- Additive Manufacturing has its applications in several industries like defence, automotive industry, surgical equipment's' design segment, etc.



Types of 3D Printing:

- **Binder Jetting:**
  - Binder jetting, also known as material jetting or inkjet powder printing is among the most common additive manufacturing types.
  - This method works similarly to your run-of-the-mill office printer except it prints three-dimensional objects.
- **Directed Energy Deposition (DED):**
  - Directed energy deposition (DED) utilizes welding principles to create three-dimensional objects.
  - The material typically metal wire or powder is melted by a focused energy source like a laser or electron beam.
  - The liquid material is then precisely poured onto the build platform, where it quickly hardens, forming a layer. This process repeats until the object is finished printing.
- **Material Extrusion:**
  - Material extrusion works similarly to a hot glue gun.
  - The material feeds into the printer from a coil.
  - The tip of the nozzle heats and melts the material.
  - The liquid material is then placed layer by layer on the build platform, where it can cool and solidify, forming the object.

- **Powder Bed Fusion (PBF):**
  - Powder bed fusion, otherwise known as electron beam melting (EBM), starts with a large bed of powdered material, typically plastic, metal, sand, or ceramic powders mixed with sand.
  - The powder is selectively fused together using a laser or electron beam.
  - Once a layer of material is fused, the working area moves down, and the new layer is built on top using the same process.
- **Sheet Lamination:**
  - Sheet lamination, otherwise known as **ultrasonic additive manufacturing (UAM)** or laminated object manufacturing (LOM) is an additive manufacturing process that stacks thin sheets of material and bonds them together through ultrasonic welding, bonding, or brazing.
- **Vat Polymerization:**
  - Vat polymerization is similar to powder bed fusion, except instead of a bed of powder, it uses a vat of photopolymer resin, which is hardened in layers by an ultraviolet laser.
- **Material Jetting:**
  - Similar to binder jetting, material jetting layers material to construct an object.
  - However, instead of layering adhesive on a bed of powder, material jetting melts wax-like materials and precisely deposits droplets onto the build platform.

3. CARBON DATING

CONTEXT

The District Court in Varanasi allowed a petition seeking **Carbon Dating** of the structure inside the Gyanvapi mosque that the Hindu side has claimed is a '**Shivling'.**

What is Carbon dating?

- It is a widely-used method applied **to establish the age of organic material, things that were once living.**
  - Living things have carbon in them in various forms.
- The dating method makes use of the fact that a particular isotope of carbon called C-14, with an atomic mass of 14, is radioactive, and decays at a rate that is well known.
  - The most abundant isotope of carbon in the atmosphere is carbon-12 or a carbon atom whose atomic mass is 12.
- A very small amount of carbon-14 is also present.

Process:

- Plants get their carbon through the process of photosynthesis, while animals get it mainly through food.
  - Because plants and animals get their carbon from the atmosphere, they too acquire carbon-12 and carbon-14 isotopes in roughly the same proportion as is available in the atmosphere.
  - When they die, the interactions with the atmosphere stop.

- Now, carbon-12 is stable and does not decay, while carbon-14 is **radioactive**. Carbon-14 reduces to one-half of itself in about 5,730 years.
  - This is what is known as its **'half-life'.**
- So, after a plant or animal dies, the ratio of **carbon-12 to carbon-14** in the body, or its remains, begins to change.
- This change can be measured and can be used to deduce the approximate time when the organism died.

4. CARBON DATING METHOD: ISSUES & SOLUTION

CONTEXT

A new study shows a way to use **calcium-41** the same way **carbon-14** has been used in **carbon-dating,** but with several advantages.

What is Radiometric dating?

- Radiometric dating is a method used to determine the age of organic materials by measuring the **decay of radioactive isotopes** present in them.
- Specifically, carbon-14 dating is a commonly used radiometric dating technique for estimating the age of once-living organisms.
- When an organism is alive, it absorbs and loses carbon-14 atoms through various biological processes.
- However, once the organism dies, the intake of carbon-14 ceases, and the existing carbon-14 begins to decay.
- By comparing the relative abundance of carbon-14 in the remains of the organism with the expected amount, scientists can estimate the time of death.

What is the issue with this method?

Carbon-14 has a half-life of 5,700 years, so the **carbon dating technique** can't determine the age of objects older than around 50,000 years.

- A significant early issue with the method was to detect **carbon-14 atoms**, which occur once in around **10^{12}carbon atoms.**
- **Calcium-41** is rarer, occurring once in around **10^{15}calcium atoms.**
- In the new study, researchers pitched a technique called **atom-trap trace analysis (ATTA)** as a solution.
  - ATTA is sensitive enough to spot these atoms; specific enough to not confuse them for other similar atoms; and fits on a table top.
  - In ATTA, a laser's frequency is tuned such that it imparts the same energy as required for an electron transition in calcium-41.
  - The electrons absorb and release this energy, revealing the presence of their atoms.

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