



TARGET PRELIMS

CURRENT AFFAIRS PROGRAM 2023

by SANTOSH KUMAR



ONE STOP SOLUTION FOR ALL YOUR CURRENT AFFAIRS REQUIREMENTS FOR CSE PRELIMS 2023

Exhaustive Coverage
of Current Affairs
for



Science &
Technology



Environment &
Ecology



Indian
Economy



Indian
Polity



International
Bodies



Geography



Mapping



Art & Culture

Resources Covered / Special Sessions



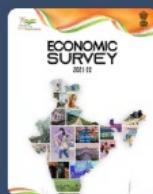
The Indian Express



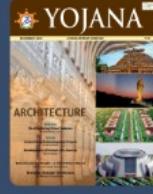
The Hindu



DownToEarth



Economic Survey



Yojana



Kurukshetra



PIB



Union Budget

Printed class notes to ensure that focus of the class is on understanding concepts

Focus
on Solving lots
of MCQs

- Solve atleast 25 MCQs in every class
- Sectional Tests after completion of every Subject
- Four Full tests (complete Syllabus) in May 2023
- Revise through 500 Questions (RTFQ) including relevant past year questions for Science, Environment and Economy

At least 3 classes every week (Friday-Saturday-Sunday)

Start Date
7th Jan

Fee

₹15,000 + GST (Offline)
₹12,000 + GST (Online)

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TARGET PRELIMS 2023

CURRENT AFFAIRS PROGRAM

BOOKLET-1; S&T-1

BIOTECHNOLOGY

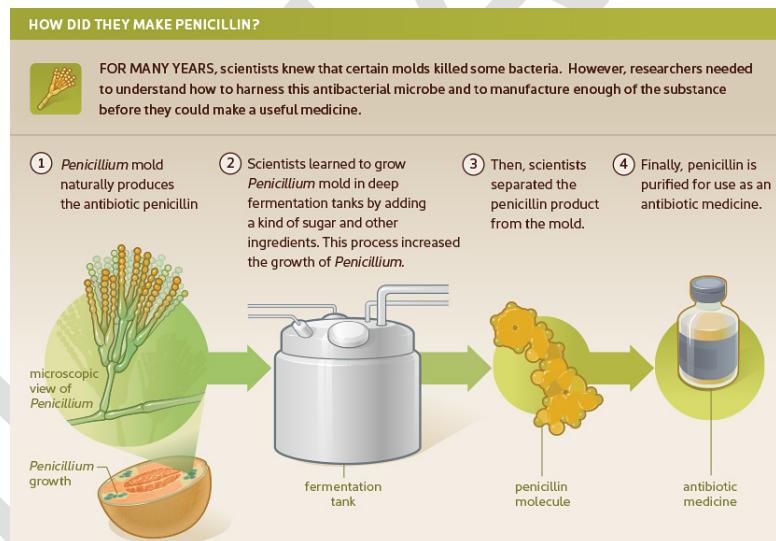
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1. INTRODUCTION

- **Definitions**
 - Biotechnology is the use of biological processes, organisms, or systems to manufacture products intended to improve the quality of human life.
 - E.g., Curd, Alcohol, GM crops, test-tube baby, developing a DNA vaccine or correcting a defective gene, are all part of Biotechnology.
 - Depending on the tools and applications, it often overlaps with the (related) fields of bioengineering, biomedical engineering, bio manufacturing, molecular engineering etc.
- **Two Sections of Biotechnology:** The entire field of Biotechnology can be divided into two sections
 - **Classical/traditional/Old Biotechnology**
 - E.g.
 - Curd being prepared with the help of microbes
 - Brewing alcohol
 - Cheese, bread and vinegar
 - Penicillin
 - In all the above product only natural capabilities of the microorganisms and cells were exploited.
 - **Modern Biotechnology**
 - Modern biotechnology refers to manipulation of genome or innate capabilities of organisms for making it more desirable or to synthesis a valuable product.
 - E.g.
 - Genetic Engineering
 - Tissue/Cell Culture (it refers to growth of tissue or cells in an artificial medium separate from the organisms)



2. BASIS OF BIOTECHNOLOGY

- Most living organisms have DNA as genetic material, DNA (Deoxyribonucleic Acid).
 - Some viruses have RNA as genetic material (e.g. Tobacco Mosaic viruses, QB bacteriophage, etc.)
- Now since all living organisms have DNA, it is possible to make changes, mix and match and this gives rise to possibility of the use of biotechnology.

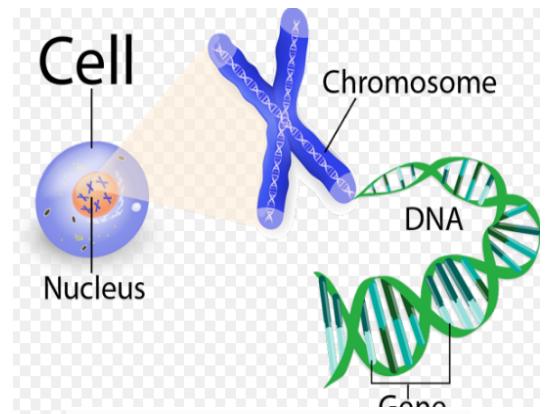
1) BASICS UNDERSTANDING OF GENETIC MATERIAL

A) GENE

- It is basic physical and functional unit of hereditary. It contains the code for a molecule that has a function. They act as instructions to make molecules called proteins
- Genes are located on DNA. It is a short section of DNA. DNA can be cut and separated, forming a sort of 'bar code' that is different from one person to the next.
- In humans, genes vary in size from a few hundred DNA bases to more than 2 million bases.
- The Human Genome Project has estimated that humans have between 20,000 and 25,000 genes.

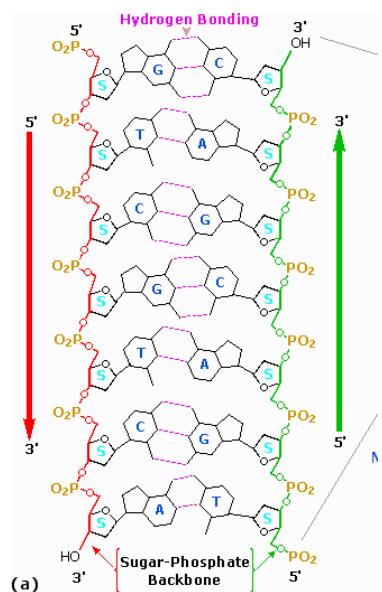
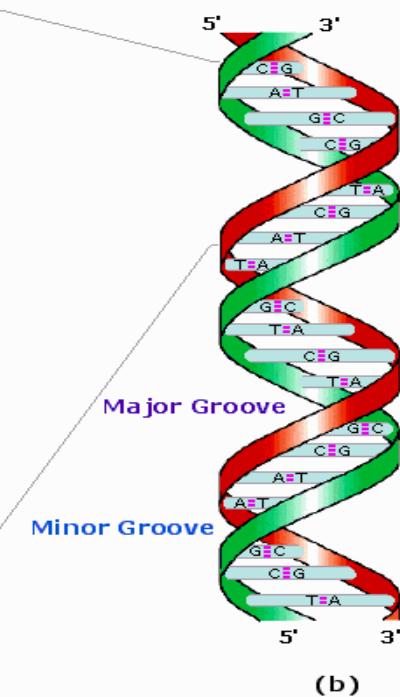
Gene Mapping

- Determining the gene's functionality and position of the gene in the chromosome is called gene mapping.



B) DNA (DEOXYRIBONUCLEIC ACID)

- DNA is the hereditary material in humans and almost all other organisms. Nearly every cell in a person's body has the same DNA. Most DNA is located in the cell nucleus (where it is called nuclear DNA), but a small amount of DNA can also be found in the mitochondria (where it is called **mitochondrial DNA or mtDNA**)
- DNA is long polymer of deoxyribonucleotides. I.e. a deoxyribonucleotide is the monomer, or single unit, of DNA, or deoxyribonucleic acid.
- The length of the DNA is usually defined as number of nucleotides (or a pair of nucleotides referred to as base pairs) present in it.
- Human DNA is **3.3×10^9 base pairs**.
- Structure of Polynucleotide Chain**
 - A nucleotide has three components - a nitrogenous base, a pentose sugar, (deoxyribose in case of DNA), and a phosphate group.
 - There are two types of nitrogenous base.
 - Purines** (Adenine and Guanine)
 - Pyrimidines** (Cytosine, Uracil and Thymine)



- Note: Thymine is only found in DNA and Uracil only in RNA
- DNA bases pair up with each other, A with T and C with G, to form units called base pairs.
- The bases in two strands are paired through hydrogen bond (H-bonds) forming base pairs (bp). Adenine forms two hydrogen bonds with Thymine from opposite strand and vice-versa. Similarly, Guanine is bonded with Cytosine with three H-bonds.
- The structure of double helix is somewhat like a ladder, with the base pairs forming the ladder's rungs and sugar and phosphate molecules forming the vertical sidepieces of the ladder.
- The two chains are coiled in right-handed fashion.

a) **WHAT IS DNA FINGERPRINTING?**

- DNA fingerprinting, also called DNA typing, DNA profiling, genetic fingerprinting, genotyping, or identity testing is a method of isolating and identifying variable elements in the base pair sequence of DNA.
- This technique was developed in 1984 by British geneticist **Alec Jeffreys**, after he noticed that certain sequences of highly variable DNA (known as **minisatellites**), which don't contribute to the function of genes, are repeated within genes.
- It was also noticed that each individual has a unique pattern of minisatellites (the only exceptions being multiple individuals form a single zygote, such as identical twins).
- **DNA fingerprinting is a technique** that simultaneously detects lots of mini satellites in the genome to produce a pattern unique to an individual. This is a **DNA Fingerprint**.
- **How is DNA fingerprint created?**
 - **Obtaining a sample of cells:** such as skin, hair, or blood cells which contain DNA.
 - **Extract** and purify DNA from these cells.
 - **PCR** is used to amplify the desired fragments of DNA many times over creating thousands of copies of the fragments.
 - Once an adequate amount of DNA has been produced using PCR, the exact sequence of nucleotide pairs in a segment of DNA can be determined by using one of several biomolecular sequencing methods.
- **Application of DNA Fingerprinting:**
 - **Identification:** It is a forensic technique used to identify individuals/ dead bodies by characteristics of their DNA.
 - **Solving legal disputes:**

- **Physically connect a piece of evidence to a person** or rule out someone as a suspect.
- To determine **paternity and other relationships**

- **Medical applications:**
 - Match tissue of organ donors with those of people who need transplant
 - Identify diseases that are passed down through your family
 - Help find cure for those diseases, called hereditary diseases.

- **Problems:**
 - **Sources of errors:** Sample contamination, faulty preparation procedures, and mistakes in interpretation of results are major sources of error.

b) DNA BARCODING

- **DNA Barcoding** is a tool for rapid species identification based on DNA sequence. It uses as short section of DNA from a specific gene or genes.
 - The way barcodes on a product, uniquely identifies a commercial product, in the same way, short gene segments – known as **DNA barcodes** – are unique for each species.
 - DNA barcoding has emerged as a global standard for fast and reliable genetic species identification of animals, plants and fungi.

- **Different gene regions are used to identify the different organismal groups using barcoding:**
 - For e.g., for animals (birds, butterflies, fish) and some protists – a short DNA sequence of COI gene found in mitochondrial DNA is used.
 - Similarly, Species identification of land plants is enabled by the combination of two different chloroplast gene regions – matK and rbcL.
 - Fungi species can be determined by the ITS region.

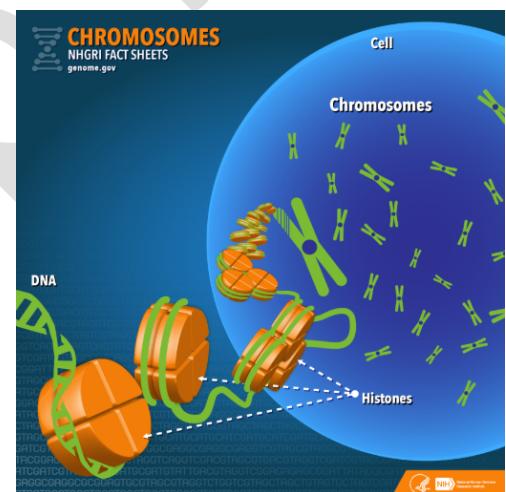
- **The ultimate goal of DNA barcoding is to build a publicly accessible reference database** with species-specific DNA barcode sequences.

- **Various methods of DNA Barcoding:** Barcoding can be done from tissue from a target specimen, from a mixture of organisms (bulk samples), or DNA present in environmental samples (e.g. water or soil). The methods barcoding will differ in each of these cases:
 - **Tissue Samples**
 - **Bulk Samples:** This sample contains several organisms from the taxonomic group under study.
 - E.g. – Aquatic macroinvertebrate samples collected by kick-net, or insect samples collected with a Malaise trap.

- **eDNA samples:** The environmental DNA (eDNA) method is a non-invasive approach to detect and identify species from cellular debris or extracellular DNA present in environmental samples (e.g., water or soil).
 - The main difference between bulk samples and environmental samples is that the bulk sample usually provides a large quantity of good-quality DNA.
- **Applications of DNA Barcoding:**
 - Identifying plant leaves (even when flowers and fruits are not available)
 - Identifying pollen collected on the bodies of pollinating animals
 - Identifying insect larvae which may have fewer diagnostic characteristics than adults
 - Investigating the diet of an animal based on its stomach content

C) CHROMOSOMES

- In the nucleus of each cell, the DNA molecule is packaged into thread-like structure called chromosomes.
- Each chromosome is made up of DNA tightly coiled many times around protein called histones that support the structure.
- The adjacent figure shows the relation between chromosome and DNA molecule



D) RNA

- RNA stands for ribonucleic acid. It is a molecule with long chain of nucleotides. A nucleotide contains a nitrogenous base, a ribose sugar, and a phosphate.

- Like DNA, RNA is also vital for living cells.

- Shape and structure**

- It comes in a variety of different shapes.
- Unlike double-stranded DNA, **RNA is a single-stranded molecule in many of its biological roles** and has a **much shorter chain of nucleotides**.
- However, **RNA can, by complementary base pairing, form intra-strand** (i.e., single-strand) double helixes, as in tRNA

- Functions of RNA**

- Carrying **genetic material** in some viruses
- The main job of RNA is to **transfer the genetic code needed for the creation of proteins from the nucleus to the ribosome**. The process prevents DNA from having to leave the nucleus. This keeps the DNA and genetic code protected from damage. Without RNA, proteins could never be made.
- Some RNAs act as enzymes. Such RNA enzymes are called ribozymes and they exhibit many of the features of a classical enzyme.

- mRNA, rRNA, and tRNA**

- RNA is central to protein synthesis.
 - First a type of RNA called messenger RNA (mRNA) carries information from DNA to structure called ribosomes.
 - These ribosomes are made from proteins and ribosomal RNA (rRNAs).
 - These all come together and form a complex that can read messenger RNAs and translate the information they carry into proteins. This requires the help of transfer RNA or tRNA.
- RNA is formed from DNA by a process called transcription. This uses enzymes like RNA polymerase.

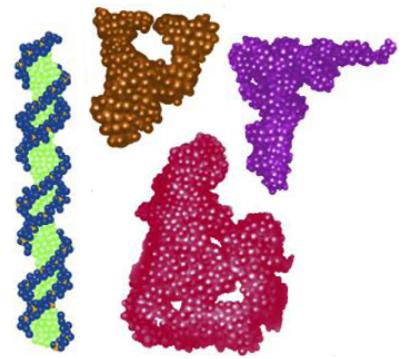
- Transcriptome** is the set of all messenger RNA molecules in one cell or a population of cells.

- Because transcriptome includes all mRNA transcripts in the cell, the transcriptome reflects the genes that are being actively expressed at any given time.

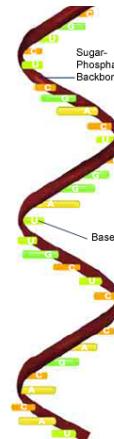
Biotechnology makes it possible to move gene which is responsible for some particular feature from one organism to another.

3. PROCESS OF MANUFACTURE OF PROTIEN

- Protein synthesis starts when mRNA moves from nucleus to a ribosome on the surface of RER.



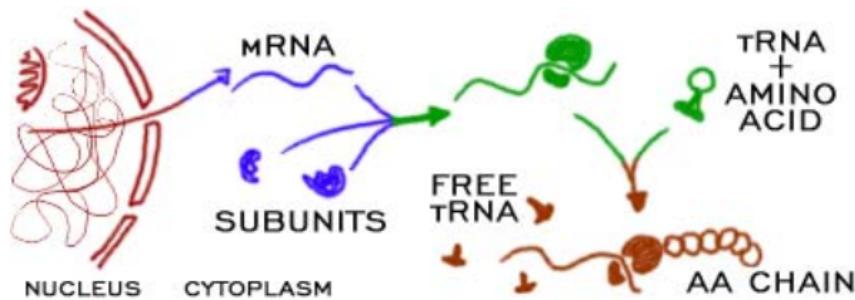
RNA comes in a variety of different shapes.
Double-stranded DNA is a staircase-like molecule.
Image Credit: National Institute of General Medical Sciences



Ribonucleic acid (RNA) has the bases adenine (A), cytosine (C), guanine (G), and uracil (U). Image Credit: National

- The two sub-units of ribosomes come together and combine with mRNA. They lock onto the mRNA and start the protein synthesis.
- Ribosome builds the amino acid chain. The process is simple. First, you need an amino acid. Another nucleic acid that lives in the cell is **transfer RNA**. It is bonded to amino acids floating around the cell. With mRNA offering instructions, the ribosome connects to a tRNA and pulls off one amino acid. The tRNA is then released back into the cell and attached to another amino acid.
- When the protein is complete RER pinches off a vesicle. That vesicle, a small membrane bubble, can move to the cell membrane or the Golgi apparatus. Some of the protein will be used in the cell and some will be sent out into intercellular-space.

Mixing and Matching Amino Acids



1) RNA INTERFERENCE TECHNOLOGY

- » RNA Interference Technology (RNAi) is a biological process in which RNA molecules inhibit gene expression or translation, by **neutralizing targeted mRNA molecules**.
- » It is also known as **co-suppression, post-transcriptional gene silencing (PTGS)**, and **quelling**.
- » Here mechanisms are developed to degrade mRNA molecules. This decreases their activity by preventing translation, via gene silencing.
- » **Functions/Applications**
 - » RNA interference is a **vital part of the immune response** to viruses and other foreign genetic material, especially in plants where it may prevent the self-propagation of transposons.
 - » RNA interference has an **important role in defending cells against parasitic nucleotide sequences** – virus etc.
 - » It can be useful to **study the function of a gene** in experimental biology in cell culture.

4. TWO CORE TECHNIQUES THAT ENABLED BIRTH OF MODERN BIOTECHNOLOGY ARE:

1) GENETIC ENGINEERING

- » Technique to alter the chemistry of genetic material (DNA and RNA), to bring about desired modifications into host organisms and thus change the phenotype of the host organisms.

- » Phenotype: The set of observable characteristics of an individual resulting from the interaction of its genotype with the environment.
- » Genotype: the genetic constitution of an individual organism.

Jelly fish glow at night. If we want other living organism to glow at night, we can extract the gene which is responsible for this glow and put it in the new host organism.

» **Advantage of genetic engineering over traditional hybridization process**

- » Traditional hybridization processes used in plant and animal breeding, very often lead to inclusion and multiplication of undesirable genes along with desired genes.
- » The techniques of genetic engineering which include creation of **recombinant DNA**, use of **Gene Cloning**, and **gene transfer**, overcomes the above limitation and allows us to isolate and introduce only one or a set of desirable genes without introducing undesirable genes into the target organisms.

2) MAINTENANCE OF STERILE (MICROBIAL CONTAMINATION-FREE) AMBIENCE IN CHEMICAL ENGINEERING PROCESS

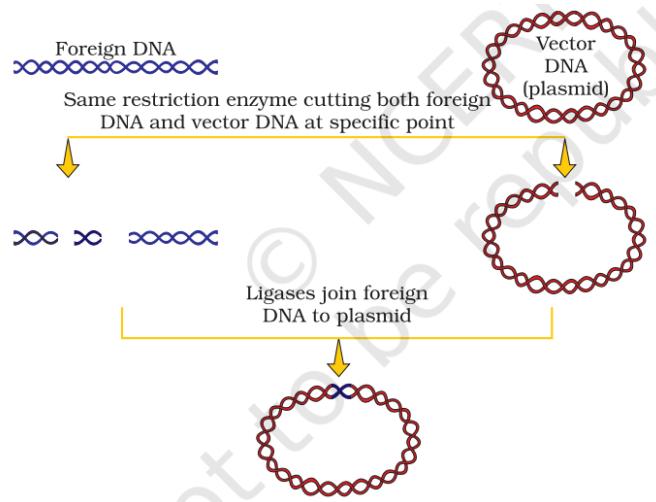
- » To enable growth of only the desired microbe / eukaryotic cell in large quantities for the manufacture of biotechnological products like antibiotics, vaccines, enzymes etc

5. TOOLS OF RECOMBINANT DNA TECHNOLOGY

Genetic engineering or recombinant DNA technology can be accomplished only if we have key tools, i.e., **restriction enzymes**, **polymerase enzymes**, ligases, vector and the host organisms.

1) RESTRICTION ENZYMES

- A restriction enzyme or restriction endonuclease is an enzyme that cuts DNA at a near specific recognition nucleotide sequence known as restriction sites.
 - To cut DNA, all restriction enzymes make two incisions, once through each sugar-phosphate backbone (i.e. each strand) of the DNA double helix.
- Restriction endonuclease are used in genetic engineering to form 'recombinant' molecule of DNA, which are composed of DNA from different sources/genomes.
- When cut by same restriction enzyme, the resultant DNA fragments have the same kind of 'sticky-ends' and, these can be joined together (end-to-end) using **DNA ligases**.



2) CLONING VECTOR

- They are used to transfer the foreign DNA to host DNA.
- Vectors used at present are engineered in such a way that they help easy linking of foreign DNA.

3) DNA LIGASE

- » It is a specific type of enzyme, a ligase that facilitates the joining of DNA together by catalyzing the formation of a phosphodiester bond.

4) HOST ORGANISMS

- The organism where the gene would be inserted.
- Techniques such as micro-injection are used. Here recombinant DNA is directly injected into nucleus of an animal cell.
- In other methods suitable for plants, the cells are bombarded with high velocity microparticles of gold or tungsten coated with DNA in a method known as **biotic or gene gun**.
- Another method is using 'disarmed pathogen' vectors, which when allowed to infect the cell, transfer the recombinant DNA into the host.

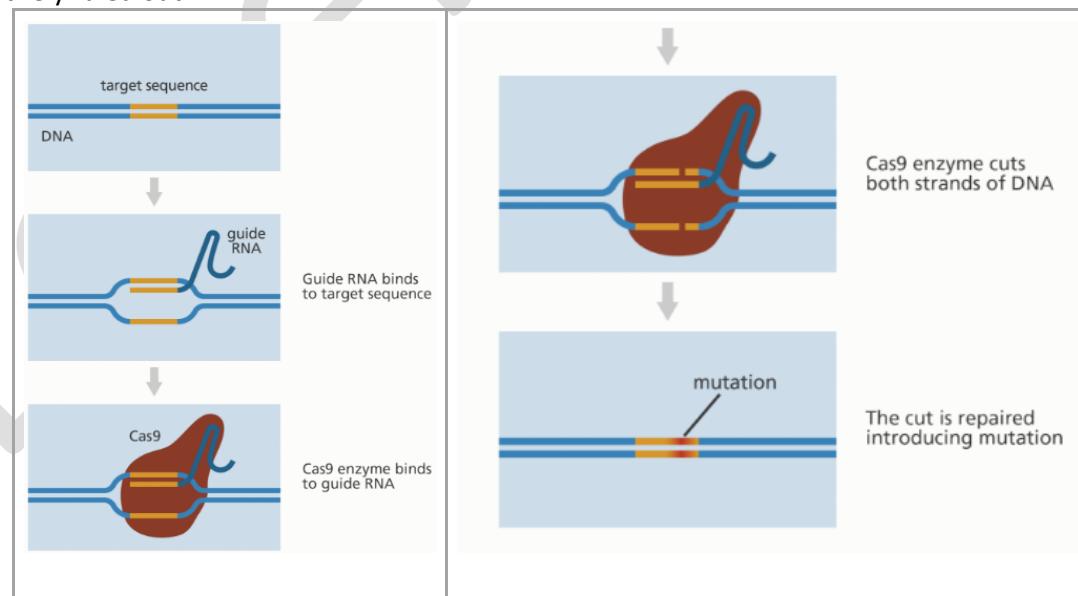
6. CRISPR-CAS9

- **Why in news?**
 - CRISPR is being used for solving a lot of health problems. Over the last 3 years, the gene-editing technology with near unlimited potential has produced flawless results in clinical trials (Sep 2022)
 - India has approved a 5-year project to develop CRISPR to cure sickle cell Anaemia (2021)
- **What is Gene Editing:**
 - Gene editing is the process of genetic engineering in which DNA is inserted, deleted or replaced in the genome of an organism using engineered nucleases, or "molecular scissors". These nuclease or enzymes create site-specific double strand breaks (DSBs) at desired locations. The induced double strand breaks are repaired through end joining or recombination, resulting in targeted mutation.
- What is **(CRISPR/CAS9)?**
 - CRISPR-CAS9 is a new genome editing tool, which is simpler, faster, cheaper, more versatile and more accurate than the previous techniques of editing DNA and has wide range of potential applications.
 - **Background: The inspiration for CRISPR:**
 - The inspiration of developing CRISPR CAS9 came from the **CRISPR system used by several bacterias** to fight against bacteriophages.

- CRISPR (Clustered Regularly Interspaced Short Palindromic Sequence) are short DNA sequences found in the genome of Prokaryotic organisms such as bacteria, which are reminders of various bacteriophage (virus) attacks that the bacteria successfully defended against. Cas9 enzyme (part of the bacteria's defence mechanism) uses these flags to precisely target and cut any foreign DNA, thus protecting the bacteria from future attacks by similar bacteriophages.
- **Emmanuelle Charpentier of France and Jennifer Doudna** of the US won the Nobel Chemistry Prize in 2020 for developing CRISPR-Cas9. This was the first time a Nobel Science prize has gone to a women-only team.

NOTE: Prof. Charpentier, 51, and Prof. Doudna, 56, were just **the sixth and seventh women to receive the Nobel Prize in Chemistry**.

- How does CRISPR-CAS9 work? (Clustered Regularly interspaced short palindromic repeats)
 - https://www.youtube.com/watch?v=UKbrwPL3wXE&ab_channel=MayoClinic
 - The first task is to identify the particular sequence of genes that is cause of problem and thus have to be deleted.
 - Once this is done, an RNA molecule (called **guideRNA**) is programmed to locate this sequence of DNA stand, just like the 'find' or 'search' function of a computer.
 - After this, a special protein called Cas9 (CRISPR associated Protein 9), which is often described as '**genetic scissors / molecular scissors**', is used to break the DNA strand at specific points so that bits of DNA can then be added or removed.
 - A DNA strand, when broken, has a natural tendency to re-attach and heal itself. But if the auto-repair mechanism is allowed to continue, the bad sequence can regrow. So, scientists intervene during the auto-repair process by supplying the correct sequence of genetic codes, which attaches to the broken DNA strand.
 - The entire process is programmable, and has remarkable efficiency, though chances of error are not entirely ruled out.



- Applications of CRISPR-CAS9
 - The technology has had a **revolutionary impact** on life science.

- Its applications include:

- **Curing diseases genetic in nature** – i.e., the diseases are caused by unwanted changes or mutations in genes. These include common blood disorders like sickle cell Anaemia, eye diseases including color blindness etc.
- Several therapeutic interventions using CRISPR for diseases like thalassemia or sickle cell Anaemia have gone into clinical trials, mainly into USA and the initial results have been flawless. The case of **Victoria Gray**, suffering from sickle cell Anaemia, who was in the first batch of patients who were treated using CRISPR-based solutions, have been widely tracked. Gray is now considered cured of the disease.
- Indian government has also approved a five-year project to develop CRISPR to cure sickle cell Anaemia. **Debojyoti Chakraborty** and **Souvik Maiti** at CSIR's Institute of Genomics and Integrative Biology have indigenously developed a CRISPR-based therapeutic solution for sickle cell anaemia. It is now being readied for clinical trials.
- **Deformities arising out of abnormalities in gene sequences** – like stunted or slow growth, speech disorders, or inability to stand or walk can also be treated by CRISPR.
- **Developing GM crops and animals.**
 - For e.g., Japan has already approved the commercial cultivation of a tomato variety that has been improved using CRISPR-based intervention.
 - In India, several research groups are working on CRISPR-based enhancements for various crops including rice and banana.

- **Limitation**

- **Potential of misuse**: (bioterrorism; designer babies)
- **Collateral Damage (Knock-on Effect)**:
- **Ethics of CRISPR** – Should humans be allowed to modify how the nature works?

1) CRISPR GENE-EDITING POSSIBLE IN TEMPERATURE SENSITIVE ORGANISMS, PLANT & CROP VARIETIES (NOV 2022; SOURCE: PIB)

- As a further step to advance the CRISPR platform into forefront of biomedical and analytical biotechnology, scientists at Raman Research Institute (RRI), an autonomous institute of DST, have explored temperature-dependent binding and release of cleaved products by the Cas9 enzyme.
- The study demonstrated that the Cas9 enzyme strongly binds to the target at very low temperatures and remains bound to the cleaved DNA products even after the enzyme has done its job.
- The results on Cas9-DNA binding and release mechanisms will provide valuable insights for developing temperature-dependent applications of the CRISPR-Cas9 technology.

2) CRISPER TECHNOLOGY INSERTED GENES THAT ALLOW IMMUNE CELLS TO ATTACK CANCER CELLS (NOV 2022: SOURCE – THE HINDU)

- In the past, CRISPR gene editing tool has been used in humans to remove specific genes to allow the immune system to be more activated against cancer.
- For the first time, scientists have used CRISPR to insert gene that allow immune cells to attack cancer cells, potentially leaving normal cells unharmed and increasing the effectiveness of immunotherapy.
 - The research, published in the journal *Nature*, used CRISPR to not only take out specific genes, but also to insert new ones in immune cells efficiently redirecting them to recognize mutations in the patient's own cancer cells.
- The human immune system has specific receptors on immune cells that can specifically recognize cancer cells and differentiate them from normal cells. These are different for every patient, so finding an efficient way to isolate them and insert them back into immune cells to generate a personalized cell therapy to treat cancer is key to making the approach feasible on a large scale.
- Significance
 - This is a leap forward in developing a personalized treatment for cancer, where the isolation of immune receptors that specifically recognize mutations in the patient's own cancer are used to treat the cancer.
 - The generation of personalized cell treatment for cancer would not have been feasible without the newly developed ability to use the CRISPR technique to replace the immune receptors in clinical-grade cell preparation in single step.
- The researchers reported treating of 16 patients with a variety of solid cancers including colon, breast and lung cancers.

3) HOW GENE THERAPY USING CRISPR CAN CURE CANCER (DEC 2022: SOURCE THE HINDU)

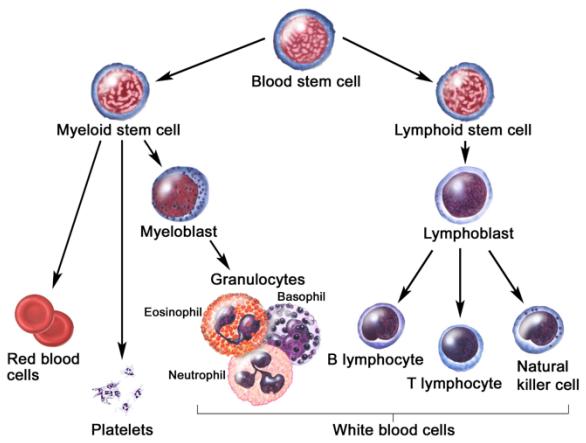
- Why in news?
 - Scientists in the United Kingdom testing a new form of cancer therapy, reported success of teenage girl, Alyssia, with a form of cancer called T-cell acute lymphoblastic leukaemia (Dec 2022)
- What is T-cell acute lymphoblastic leukaemia (T-ALL)
 - It is a type of cancer where the T-cells, which are a class of white blood cells, equipped to hunt and neutralize threats to the body, turn against the body and end up destroying healthy cells that normally help with immunity. The disease is rapid and progressive and is usually treated by chemotherapy and radiation therapy.
- How gene therapy treated this?
 - Alyssia, a teenage girl, had tried several of the standard treatments including chemotherapy and radiation. But the treatment wasn't successful.

- Then she enrolled in an experimental trial conducted by doctors and scientists at the University College, London and Great Ormond Street Hospital. She was the **first patient to receive experimental gene therapy that relied on a new technique called 'base-editing'**.
- **What is base editing?**
 - When a misarrangement in the sequence of nitrogen bases (ATCG) is edited to arrange it properly, it is called base editing. David Liu, of the Broad Institute, Massachusetts has improvised on the CRISPR-cas9 to be able to directly change certain bases: thus, a C can be changed into G and T into an A. While still a nascent technology, base editing is reportedly more effective at treating blood disorders which were caused by so-called single point mutations, or when a change in a single base pair can cause terminal disease.
- **Alyssia's case:**
 - In Alyssia's case, her T-cells – perhaps because of a misarrangement in the sequence of bases – had become cancerous. The objective of the gene therapy in the case of T-cell leukemia was to fix her immune system in a way that it stops making cancerous T-cells.
 - First, healthy T-cells were extracted from a donor and put through a series of edits.
 - The first base edit blocked the T-cells targeting mechanism so it would cease attacking Alyssia's body.
 - The second removed a chemical marking, called CD7, which is on all T-cells.
 - Third prevented the T-cells from being killed by a chemotherapy drug.
 - Finally, the T-cells were programmed to destroy all cells – cancerous or protective – with CD7 marked on it.
 - After spending a month in remission, she was given a second donor transplant to regrow her immune system that would contain healthy T-cells.
 - **How effective was the treatment?**
 - Her cancer doesn't seem to have re-surfaced.
 - **More verification needed:**
 - It has been 1.5 years since she was first diagnosed with the disease and whether the treatment has reliably and entirely fixed her immune system, remains to be established.

A) UNDERSTANDING T-CELLS IN MORE DETAILS

- T cells are a type of white blood cells. They are part of immune system and develop from **hematopoietic stem cells** (blood stem cells) present in bone marrow. They help protect body from infection and may help fight cancer. They are also called T Lymphocyte and thymocyte.

- After getting born from blood stem cells, they migrate to thymus gland to develop. T-cells derive their name from the thymus. In thymus, the precursor cells mature into several distinct type of T cells. This differentiation continues after they have left the thymus.



- **One of the important functions of T-cells is immune mediated cell death** – it is carried out by two major subtypes – CD8+ “Killer” and CD4+ “helper” T cells. These are named for the presence of the cell surface proteins CD8 and CD4.
- T cells, also known as “Killer T-cells”, are cytotoxic – this means that they are able to directly kill virus-infected cells, as well as cancer cells.
- T-cells can be distinguished from other lymphocytes by the presence of a T-cell receptor (TCR) on their cell surface.

7. DARK DNA – CLASS DISCUSSION

8. SOMATIC CELL NUCLEAR TRANSFER

- In genetics and developmental biology, somatic cell nuclear transfer (SCNT) is a **laboratory technique for creating an ovum with a donor nucleus**.
 - In SCNT the nucleus, which contains the organism's DNA, of a somatic cell (a body cell other than a sperm or egg cell) is removed and the rest of the cell discarded.
 - At the same time, the nucleus of an egg cell is removed.
 - The nucleus of the somatic cell is then inserted into the unnucleated egg cell.
 - After being inserted into the egg, the somatic cell nucleus is reprogrammed by the host cell.
 - The egg, now containing the nucleus of a somatic cell, is stimulated with a shock and will begin to divide.
 - **After many mitotic divisions in culture**, this single cell forms a blastocyst (an early stage embryo with about 100 cells) with almost identical DNA to the original organism

It can be used in embryonic stem cell research, or in regenerative medicine where it is sometimes referred to as "therapeutic cloning." It can also be used as the first step in the process of reproductive cloning.

9. APPLICATIONS OF BIOTECHNOLOGY

1) GM CROPS

- GM Crops, Advantages and Controversies

- Crops whose DNA has been altered are known as GM crops. This genetic modification of crops can add or remove certain characteristics from the plant and thus can bring many advantages.
 - Make crops more tolerant to anti-biotic stresses (cold, drought, salt, heat) etc.
 - E.g., GM Rubber developed by Rubber Research Institute of India
 - Make plants **Pest Tolerant**.
 - Reduces reliance on chemical pesticides.
 - E.g. BT cotton, BT Brinjal (in Bangladesh)
 - Help to reduce post-harvest losses
 - Enhance the **nutritional value** of food, e.g., Golden Rice (Vitamin A enriched rice)
 - Tailor-made plants to supply **alternative resources** to industries, in the form of starches, fuels, and pharmaceuticals.

A) BT COTTON

- Specific BT Toxic gene (*cry1Ac*) were isolated from *Bacillus thuringiensis* and incorporated into several crop plants such as cotton. This produces proteins that kill certain insects such as lepidopterans (tobacco budworm, armyworm), beetles, etc.
- It has been grown in India since 2002 and over the years have given increase productivity and area under crop cultivation. It has also led to decrease in insecticide which fought bollworms by 97%.
- But it has also raised concerns like increased water consumption, and emergence of pesticide resistant pests (e.g., pink bollworm), and increased use of insecticide for controlling pests like sucking pests.

B) BT BRINJAL

- Transgenic Brinjal created by inserting a **crystal protein gene (Cry1Ac)** from the soil bacterium Bacillus thuringiensis into the genome of various brinjal cultivar. It gives resistance against lepidopteron insects in particular the Brinjal fruit and shoot border (BFSB), the most common pest which affects 30-50% of the Brinjal crops.
- The crop also cleared the GEAC's biosafety test in 2009. But, government yielded to anti-GM activists and declared a moratorium in 2010 on the crop.
- But some cases of illegal BT Brinjal cultivation was observed in Haryana in 2019

- Why are some groups calling for allowing of BT Brinjal in India?
 - It had cleared the GEAC's biosafety test in 2009.
 - Increased benefit for farmer
 - When GM Crops are not officially available, farmers turn to unapproved knock offs that may not conform to accepted biosafety standards.

- Why is BT Brinjal not allowed in India? Why is it opposed by various activists?
 - There are fears that it may impact India's plant biodiversity.
 - Further, cross pollination may lead to herbicide resistant super weeds that can further threaten environment and biodiversity.
 - Health Impact is something that needs to be studied more.
 - Not so obvious benefits: A recent study from surveys of farmers indicate that 2/3rd of the farmers who moved to BT Brinjal have had a 'bad' or 'very bad' experience.

C) GM MUSTARD

- Why in news?
 - GEAC approves commercial cultivation of genetically modified mustard yet again (Oct 2022)

- What is GM Mustard?
 - DMH-11 (Dhara Mustard Hybrid) is a genetically modified (GM) mustard Hybrid.
 - GM mustard is the country's first genetically modified food crop.
 - It was developed by a team of scientists led by former Vice Chancellor Deepak Pental, of DU at Center for Genetic Manipulation of Crop Plants (CGMCP), Delhi University by crossing Indian mustard cultivars with juncea lines of East European origin like 'Early Heera' and Donskaja.

- Claim of higher yield:
 - Claims around 30% more yield than the traditional varieties

- What genetic modification was achieved and what are its benefit?
 - Barnase gene and Barster gene from Bacillus amyloliquefaciens
 - Barnase impairs pollen production
 - Barster blocks the function of Barnase
 - Hybridization becomes possible:
 - This method was used to developed DMH-11 by crossing a popular Indian mustard variety 'Varuna' (the barnese line) with an East European 'Early Heera-2' mutant (barstar).

- Arguments for and against approval of GM mustard
 - » For

- **Higher Production**
- **Reducing Import Dependency**
- **Saving Forex**
- **Keeping India Scientifically relevant**

» **Against**

- The main contention is that the GM mustard incorporates three alien genes - barnase, barstar, and bar - rendering it inherently unsafe for human and animal health.
 - But these genes have already been deployed in Canola, and we import it freely.
- Mustard is a food crop unlike cotton, so both should not be compared
- All health effects not properly known yet
- Environmental damages should be studied properly first.
- Yield claims have been challenged by many organizations

» **GEAC Approval (Oct 2022)**

- In Oct 2022, GEAC approved commercial cultivation of genetically modified mustard yet again. The approval allowed environmental release of two varieties of genetically engineered mustard, so that it can be used for developing new parental lines and hybrids under the supervision of ICAR. The environmental release of DMH-11 will allow for its seed production and testing as per existing ICAR guidelines and other extant rules/ regulations prior to commercial release. The field demonstration studies on the effect of GE mustard on honeybees and other pollinators was also allowed to be conducted.
- **Other conditions set for clearance:**
 - Approval is for limited period of 4 years and is renewable for 2 years at a time based on compliance report.
 - External experts will visit the growing sites of the crop at least once each season.
 - Applicant (Centre for Genetic Manipulation of Crop Plants) shall deposit 100 grams each of approved hybrids as well as their parental lines with the ICAR-National Bureau of Plant Genetic Resources and communicate the same to GEAC within 30 days of issue of the clearance letter for the purpose of future reference in case of trade, traceability, and dispute on account of ownership.
 - The applicant should also develop and deposit the DNA fingerprints of the approved varieties to ICAR.
 - Commercial use of DMH-11 will be subjected to the Seed Act and related rules and regulations.
- The Proposal would now go for environment ministry's clearance.
- **Criticism of Approval:**
 - An NGO Coalition for GM Free India says that since 2017, nothing much has changed. Only two additional test have been prescribed by GEAC in a perfunctory and irresponsible fashion since then as though the debate about GM mustard was about these two aspects alone.
 - **Conflict of Interest:** GEAC had set up an expert committee in Aug 2022. This was headed by a scientist from the DBT. This is a conflict of interest provided DBT is the founder of GM mustard.

D) GM RUBBER – DEVELOPED BY KERALA BASED - RUBBER RESEARCH INSTITUTE OF INDIA

- Rubber Research Institute of India have developed a plant tailored for the climatic conditions in the Northeast.
- Rubber board research farm at Sarutari on the outskirts of Guwhati now sports world's first GM rubber plant, tailored for climatic condition in the north-east.
- **Genetic Modification:** The GM rubber has additional copies of the gene MnSOD, or manganese-containing superoxide dismutase, inserted in the plant, which is expected to tide over the severe cold conditions during winter – a major factor affecting the growth of young rubber plants in the region

E) INCREASING THE NUTRIENT CONTENT – GOLDEN RICE

▫ Golden Rice

- What is Golden Rice?

- The IRRI and its national research partners have developed golden rice to complement existing interventions to address vitamin A deficiency (VAD). It is a serious public health problem affecting millions of children and pregnant women globally.
- Golden rice is variety of rice produced through genetic engineering to biosynthesize beta-carotene. Beta-carotene is a nutrient similar to what is found in orange colored fruits and vegetables and is converted into Vitamin-A as needed by the body.
- Thus, golden rice can help south and south-east Asian countries, where two-thirds or more of daily calorific intake is obtained from rice. Research has indicated that the golden rice can provide upto 50% of the daily requirement of an adult for vitamin A.



- Golden rice was one of the 7 winners of the 2015 Patents for Humanity Awards by the United States Patent and Trademark Office
- Safety Evaluation by International Rice Research Institute
 - The safety evaluation of Golden rice has shown that it is as safe and nutritious as conventional rice but comes with added benefit of beta-carotene.
- About International Rice Research Institute:
 - IRRI is the world's premiere research organization dedicated to reducing poverty and hunger through rice science; improving the health and welfare of rice farmers and consumers; and protecting the rice growing environment for future generation.
 - It is an independent, non-profit, research and educational institute, founded in 1960 by the Ford and Rockefeller foundations with support from the Phillipines government.

- The institute is headquartered in Los Banos, Philippines and has offices in 17 rice-growing countries in Asia and Africa.
- It works with in-country partners to develop advanced rice varieties that yield more grain and better withstand pests and disease as well as flooding, drought, and other harmful effects of climate change.

F) ISSUE OF ILLEGAL CULTIVATION OF GM CROPS:

- **BT Brinjal** Illegal cultivation in Haryana Rajasthan etc.
- **Sale of Illegal HTBt (Herbicide tolerant Bt) cotton seeds** has doubled this year(June 2021)
 - The HTBt cotton variant adds another layer of modification to BT cotton, making the plant resistant to the herbicide glyphosate, but has not been approved by regulators.
 - **Support for HTBt:** Groups like Shetkari Sangathan are demanding the legalization of HTBt cotton.
 - **Saves cost:** Weeding labour cost reduces, only one round of glyphosate spraying is needed to deal with the weed.
 - **Illegal sales** reduce accountability, hampers government revenue and farmers are at risk of getting wrong information.
 - **Concerns/Fears:**
 - Glyphosate have carcinogenic effect
 - Unchecked spread of herbicide resistance to nearby plants through pollination, creating a variety of superweeds etc.
- **Controversy: Is Genetically modified rice grown in India? (Oct 2021)**

2) REDUCED HEIGHT GENES (RHT): ADVANTAGES AND LIMITATIONS

Introduction

- 3) Since the 1960s and the Green Revolution, **reduced height (Rht) genes have increased global yields** because the short-stemmed wheat they produce puts more investment into the grains rather than into the stems and has improved standing ability. It leads to reduced risk of lodging, increase in partitioning and assimilation of grains, more fertile florets per spriglet and higher harvest index (the proportion of plant weight in grains).
- 4) The high yielding wheat variety developed by Borlaug, which required higher use of fertilizers and pesticides, produced bigger grains. However, the heavier grains caused the plants to become unstable and prone to lodging. Therefore, **Borlaug introduced dwarfing genes** into wheat giving plants a stronger, shorter stem that resisted lodging.
 - i) **21 reduced height genes** in wheat Rht1 – Rht21, have been described so far.

- ii) In India, the presently available semi-dwarf varieties, which were explored during the Green Revolution, carry conventional Rht1 dwarfing alleles (variant form of a given gene) and produce optimum yields under high-fertility irrigated conditions.
- **Limitations of Dwarf wheats:**
 - a) Dwarf wheats are not well adapted to deeper sowing conditions. This is due to shorter coleoptiles, and low early vigor often results into reduced seedling emergence. Further shorter coleoptiles lead to crop residue posing a problem for seedling emergence.
 - b) These wheats also don't work in drought conditions they can't be planted deep inside the soil to access moisture. They will fail to reach the surface of the soil.
- **Key Research to solve the issue:**
 - Scientists at Agharkar Research Institute (ARI), an autonomous institute of DST, have mapped to alternative dwarfing genes of Rht14 and Rht18. These genes are associated with better seedling vigor and longer coleoptiles (sheath protecting the young shoot tip).
 - **Advantages:**
 - a) The new wheat variety will be suitable for sowing under rice stubble retained condition and in dry environments. It would thus reduce the need of water and also contribute to reduction in crop stubble burning.
 - b) It also diversifies the genetic base of dwarfing genes considering diverse wheat growing zones in India.

2. **Recent research** published in the *Proceedings of the National Academy of Sciences (PNAS)* journal on 23rd Nov 2022 says that Scientists at the John Innes Centre, in collaboration with an international team of researchers, have discovered the new "reduced height" or semi dwarf gene called Rht13. The varieties of wheat with Rht13 gene could be rapidly bred into wheat varities to enable farmers to grow reduced-height wheat in drier soil conditions.

Rht13 overcome this problem of seedling emergence because the gene acts in tissues higher-up in the wheat stem. So, the dwarfing mechanism only takes effects once the seedling has fully emerged. This gives farmers a significant advantage when planting deeper in dry conditions.

3) BIOTECHNOLOGICAL APPLICATION IN MEDICINES

The recombinant DNA technological processes have had a great impact in the area of health care by enabling mass production of safe and more effective therapeutic drugs.

- Further, the recombinant therapeutics do not induce unwanted immunological responses as is common in case of similar products isolated from non-human sources.
- At present, more than 30 recombinant therapeutics have been approved for human-use the world over.
 - In India, around 12 of these are presently being marketed.

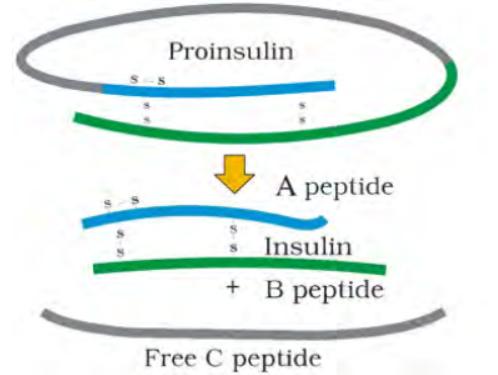
- E.g. (1. Genetically Engineered Insulin 2. Gene Therapy 3. Molecular Diagnosis 4. Disease control through GMO 5. Personal Genomics)

A) VACCINES (COVERED SEPARATELY WITH HEALTH SECTION)

- For e.g., various vaccines for COVID-19 were developed with the help of biotechnology – mRNA vaccines, vaccines with attenuated virus,

B) GENETICALLY ENGINEERED INSULIN

- Earlier, Insulin used for diabetes was extracted from pancreas of slaughtered cattle and pigs.
 - » Caused patients to develop some kind of allergies or other kinds of reactions to the foreign protein.
- **Structure of Insulin**
 - » Insulin consists of two short polypeptide chains: Chain A and Chain B, that are linked together by disulphide bridges.
 - » In Mammals, including humans, insulin is synthesized as a pro-hormone (like a pro-enzyme, pro hormone also needs to be processed before it becomes a fully mature and functional hormone) which contains an extra stretch called C peptide.
 - » This C peptide is not present in the mature insulin and is removed during maturation into insulin.
- The main challenge for production of insulin using rDNA technique was getting insulin assembled into a mature form.
- **How this was achieved through Biotechnology**
 - In 1983, Eli Lilly an American company prepared two DNA sequences corresponding to A and B, chains of human insulin and introduced them in plasmids of E. coli to produce insulin chains.
 - Chains A and B were produced separately, extracted and combined by creating disulfide bonds to form human insulin.



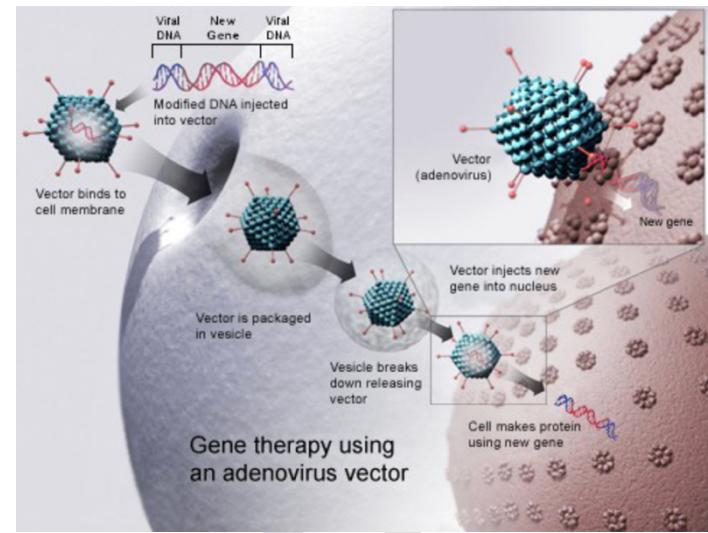
C) GENE THERAPY

- Introduction

- » If a person is born with a hereditary disease, can a corrective therapy be taken for such disease? Gene therapy is an attempt to do this.
- » **Gene therapy** refers to the process of introduction, removal or change in the content of an individual's genetic material with the goal of treating the disease and a possibility of achieving long term cure.

- » **Gene Therapy Products (GTPs)** include the mechanisms to deliver nucleic acid components by various means for therapeutic benefit to patients. They include entities that are used for things like gene augmentation, gene editing, gene silencing, synthetic or chimeric gene augmentation etc.

- **Note:** Not all medical procedures that introduce alterations to a patient's genetic makeup can be considered a gene therapy. For e.g.: Bone Marrow transplantation and organ transplants in general have been found to introduce foreign DNA into patients.



- **Advantages of promoting gene therapy**

- **Permanent result may be a possibility:**
- **High burden of rare genetic diseases in India:** Around 7 core of India's population suffers from rare genetic diseases. Gene therapy can prove to be a turning point in treatment of such genetic diseases.
- **Worldwide market for the gene therapy products** is expected to go to \$250 billion by 2025.

- **Concerns/Limitations**

- Promotion of development of gene therapy also brings along with it unique technical risks and ethical challenges.
- **Technical Challenges**
 - The gene therapy may be associated with **unwanted immune system reactions**. For e.g., when vectors (viruses) are attacked by the immune system of the body.
 - Current gene therapy mechanisms can sometimes **target the wrong cells**.
 - **The delivery viruses may mutate** and become harmful.
- **Ethical Challenges**
 - For e.g. creation of GM babies using germline gene editing by a Chinese scientist attracted global criticism and fueled debate on ethical concerns regarding applications of gene therapy technologies.
 - **Playing god** debate.

- National Guidelines for Gene Therapy Product Development and Clinical Trials – Released by ICMR in Dec 2019: Key Highlights
 - » The guidelines are aimed at ensuring that gene therapies are introduced in India and clinical trials for gene therapy can be performed in an ethical, scientific and safe manner.
 - » They provide the general principles for developing gene therapy products (GTPs) for any human ailment and provide a framework for all areas of GTP production including pre-clinical testing, clinical administration, human clinical trials, as well as long term follow up. These must follow the established general principles of biomedical research.
 - » They apply to all stakeholders involved in the field of gene therapy including researchers, clinicians, oversight/regulatory committees, industry, patient support groups and any other involved in GTP development or their application in humans and their derivatives.
 - » The guidelines will serve as a roadmap for those in the field trying to develop gene and cell therapies and will thus contribute to accelerating the development of advanced therapeutic options
 - ICMR has also proposed setting up of task force to promote gene technology research in the country.

a) PFIZER'S HEMOPHILIA B GENE THERAPY SUCCEEDS IN LATE-STAGE STUDY (DEC 2022: SOURCE – THE HINDU)

- About Haemophilia B:
 - It is a hereditary bleeding disorder. It hampers body's ability to make a blood-clotting protein called factor IX.
 - What happens when you bleed?
 - At the time of bleeding, a series of reactions take place in the body that helps blood clots to form. This process is called coagulation. It needs various proteins called coagulation, or clotting factors. A person has higher chances of bleeding if one or more of these factors are missing and are not functioning like they should.
 - Factor IX (nine) is one such coagulation factor. Haemophilia B is the result of the body not making enough factor IX. It is caused by an inherited X-linked recessive trait, with the defective gene located on the X chromosome.
 - Most people with haemophilia B are male. (Reason – Class discussion)
- Pfizer's haemophilia B gene therapy succeeds in late-stage study:
 - The study showed that a single dose of the therapy was superior to the current standard of care in helping reduce the bleeding rate in patients with moderately severe to severe forms of haemophilia B.
 - Pfizer's therapy, fidanacogene elaparovec, is designed to help patients produce factor IX themselves after a one-time treatment, as opposed to current treatments, which focus on regular infusions of the protein.

- Pfizer is also testing other experimental gene therapies in late-stage trials as potential treatments for the bleeding disorder haemophilia A and muscular disorder Duchenne muscular dystrophy.

b) NOTE: HAEMOPHILIA A

- It is also called factor VIII(8) deficiency or classic haemophilia. It is a genetic disorder caused by missing or defective factor VIII (FVIII), a clotting protein.

c) DUCHENNE MUSCULAR DYSTROPHY

- **About muscular dystrophy:**
 - It is a group of diseases that cause progressive weakness and loss of muscle mass. In muscular dystrophy, abnormal genes (mutations) interfere with the production of proteins needed to form healthy muscle.
 - There are many kinds of muscular dystrophy. The Symptoms of most common variety begin in Childhood, mostly in boys. Other types don't surface until adulthood.
 - **Sign:** The main sign of muscular dystrophy is progressive muscle weakness. Specific signs and symptoms begin at different ages and in different muscle groups, depending on the type of muscular dystrophy.
- **About Duchenne muscular dystrophy:**
 - Most common type of muscular dystrophy.
 - Although girls can be carriers and mildly affected, it's much more common in boys.
 - **Signs and symptoms** which typically appear in Childhood are:
 - Frequent falls
 - Difficulty rising from a lying or sitting position
 - Trouble running and jumping
 - Walking on the toes
 - Large calf muscle
 - Delayed growth
 - Learning disabilities.
- **Other types of muscular dystrophy include:** Becker Muscular Dystrophy

D) MOLECULAR DIAGNOSIS

- For treatment of any disease, early diagnosis and understanding its pathophysiology is very important. Using conventional methods of diagnosis (serum and urine analysis, etc.) early detection is not possible.
- Recombinant DNA technology, Polymerase Chain Reaction (PCR) and Enzyme linked Immuno-Sorbent Assay (ELISA) are some of the techniques that serve the purpose of early detection.

- PCR is a technique used in molecular biology to amplify a single copy or a few copies of a piece of DNA across orders of magnitude, generating thousands to millions of copies of a particular DNA sequence.
 - It is now routinely used to detect HIV in suspected AIDS patients. It is being used to detect mutations of genes in suspected cancer patients too.
 - ELISA is based on the principle of antigen-antibody interaction. Infection by pathogen can be detected by the presence of antigens (proteins, glycoproteins etc.) or by detecting the antibodies synthesized against the pathogens
- E.g. Tests During COVID-19
 - RT-PCR Test
 - The test detects the presence of viral RNA in human samples.
 - In this test first the viral RNA is converted into DNA (reverse transcription)
 - PCR is a process where a few copies of DNA are amplified to produce millions of copies.
 - This is done with the help of enzymes, primers, and probes.
 - Rapid Anti-Body Test
 - A rapid test is conducted to determine if there has been any kind of recent viral infection in a person's body. When a pathogen enters a human body, specific anti-bodies are released as a response to the virus. A rapid test can detect the presence of such anti-bodies in blood, serum or plasma samples question.
 - This is a simple test and can give results in 10-30 minutes.
 - It should be noted that it is not a confirmatory test for COVID-19. It is only a preliminary screening for diagnosis of coronavirus infection.
 - Further, a negative test doesn't rule out COVID-19 infection. A rapid test comes positive after 7-10 days of viral infection and remains positive for several weeks after that.

E) DISEASE CONTROL THROUGH GENETICALLY MODIFIED ORGANISMS

- By introducing sterile mosquitoes (genetically modified). (concept - not done yet)
 - Synthetic vector genome which is incapable of hosting the parasite and/or virus.
-

F) PERSONAL GENOMICS

- It is the branch of genomics concerned with sequencing and analysis of the genome of an individual. The genotyping stage employs different techniques, including single-nucleotide polymorphism (SNP) analysis chips (typically 0.02% of the genome), or partial or full genome sequencing.
- **Uses**
- Once the genotypes are known, the individual's genotype can be compared with the published literature to determine likelihood of trait expression and disease risk.
- Personalized medicines
 - It is a medical method that targets treatment structures and medicinal decisions based on patient's predicted response or risk of disease.
 - Various subcategories of personalized medicines
 - Predictive Medicines

- Precision Medicines
- Stratified Medicines
- It predicts the right kind of treatment
 - Efficacy of toxicity of chemotherapy, or radiotherapy etc.

4) TRANSGENIC ANIMALS

- Animals that have their DNA manipulated to possess and express an extra (foreign) gene are known as transgenic animals.
 - Transgenic rats, rabbits, pigs, sheep, cows and fish have been produced, although over 95% of all existing transgenic animals are mice.
 - **Why so much medical research on mice, rat?**
 - Genetic, biological and behaviour characteristics closely resemble that of humans and many symptoms of human conditions can be replicated in mice and rats.
 - We share between 95% of the same genes, and our immune system are even more compatible.
 - Therefore, the result of mouse experiment often correlates to human biology
 - Further, mice can be genetically manipulated to mimic virtually any human disease or condition.
 - **Convenience**
 - Rodents are small, easily housed and maintained, and adapt well to the new surroundings.
 - **Reproduce quickly and short lifespan:** Reproduce quickly and have short life span of 2-3 years - so several generations of mice can be observed in short span of time.
 - **Relatively Inexpensive**
 - Can be brought in large quantities from commercial producers
 - **Mild tempered and docile**
 - Rodents are also generally mild tempered and docile, making them easy for researchers to handle.
 - **How transgenic animals are helpful?**
 - **Normal physiology and development**
 - Experimenting on how alteration of genes would affect humans.
 - **Study of disease**
 - Many transgenic animals are designed to increase our understanding of how genes contribute to the development of disease.
 - **Biological Products**
 - Some medicines might require some biological products which are often expensive to produce.
 - Transgenic animals that produce useful biological products can be created by the introduction of portion of DNA (or genes) which code for a particular product.
 - E.g. : Human protein (α -1-antitrypsin) used to treat emphysema.

- In 1997, the first transgenic cow - Rosie, produced human protein-enriched milk (2.4 grams per liter).
 - The milk contained the human alpha-lactalbumin and was nutritionally a more balanced product for human babies than natural cow milk.
- Vaccine Safety
 - Transgenic mice are being developed for use in testing of safety of vaccines before they are used on humans.
 - Transgenic mice are being used to test the safety of the polio vaccine.
- Chemical safety testing
 - This is known as toxicity safety testing.
 - The procedure is same as used for testing toxicity of drugs.

5) BIOTECHNOLOGY AND ENVIRONMENT

A) GM ALGAE, CROPS ETC. CAN PROVIDE MORE BIOMASS FOR BIOFUEL.

B) BIODIVERSITY CONSERVATION

- a. E.g. -> De-extinction of species; **Colossal** is a new bioscience and genetics company, with the idea of bringing many extinct species back to life. Scientists at Harvard University in the USA would insert the Giant Woolly mammoth's (extinct 4,000 years ago) genes responsible for tiny ears, subcutaneous fat and hair length and color into living elephant skin cells. Once they are successful in bringing these hybrids back to life, Colossal will proceed with the ultimate goal of reviving the ancient extinct animals by producing more such hybrids.

Criticism: Immoral; revival of these species may threaten the existing ecosystem and disturb the food chain which has evolved over the years; Rather than focusing on revival of long extinct species, biotechnology should focus on protecting the existing ones.

C) TO DETECT INVASIVE SPECIES:

- **Environmental DNA based assay to detect invasive catfish in waterbodies** (Nov 2022 – Source: DTE)
 - Conventional methods to detect invasive species like using nets, traps, and visual observations, are cumbersome, the researchers from CCMB now have developed Environmental DNA (e-DNA) based molecular methods to provide a time and cost-effective alternative.
 - **eDNA** is defined as “genetic material obtained directly from environmental samples (soil, sediments, water etc.) without any obvious signs of the biological source material. It is an efficient, non-invasive and easy-to-standardize sampling approach. It can be obtained from ancient as well as modern environment. With scientific advancements in DNA sequencing technologies, the technique is increasingly being used for biodiversity monitoring.

- CSIR-CCMB has designed a molecular assay utilizing eDNA to specifically detect this invasive catfish in Indian ecosystem, which is affordable and quick, and will be very useful tool in conservation management. They use a reliable eDNA-based quantitative PCR assay to detect the African Sharptooth Catfish from water samples in the aquatic system.

10. OTHER TOPICS

1) GENE MAPPING / GENE SEQUENCING

2) EARTH BIO GENOME PROJECT

3) DARK DNA

4) STEM CELL RESEARCH

5) CHIM STUDIES IN INDIA

6) SYNTHETIC BIOLOGY

11. OTHER RECENT DEVELOPMENTS

1) FRUITY FLY: NOVEL METHOD TO STUDY NUCLEAR MATRIX

- » **Why in news?**
 - » Using a novel method, a group of researchers from CSIR-Centre for Cellular and Molecular Biology, Hyderabad (CCMB) and Tata Institute for Genetics and Society, Bengaluru (TIGS), have established a way of studying the nuclear matrix of the fruit fly (*Drosophila melanogaster*) without removing the nucleus from the embryo. (Aug 2022)
- » **What is Nuclear Matrix?**
 - » The Nuclear matrix is a scaffolding that helps package the genome differently in different types of cells. It gives an organization and architecture to the nucleus.
 - » **How was nuclear matrix studied so far?**
 - » So far, nuclear matrix was studied, mainly by isolating it in nuclei that have been taken out from the fruit fly embryos.
 - » Using biochemical means, if the nucleus is taken out and treated with an enzyme that digests all the DNA, then washed with a solution of high salt concentration so that viable DNA proteins or protein-protein interactions are removed, what is thus left is a fibrous meshwork of proteins called the nuclear matrix.
 - » Nuclear matrix is jelly-like nuclear matrix.

- » This is a dynamic material providing access for the regulations of different genes in different cells.
- » **Understand the need of Nuclear Matrix**
 - » We have 220 different types of cells in the body, but all contain identical genome. Despite this, different cells perform different function. (For e.g., same genome sequence is present in neurons, where it works for thinking; in the liver, the same sequence enacts metabolism; and in intestine, it works to digest)
 - » Some genes are expressed in one type of cell, whereas others are expressed in other cells. So, the genome, despite carrying all the genetic material, is packaged such that some genetic material is hidden in such a way that it is never seen by transcription machinery.
 - » So, this information is packaged differently in different types of cells. In our body, we have 220 different kinds of cells. This means that the same genome is packaged in 220 different ways.
- » **Advantage of the new technique?**
 - » The novel method developed by CCMB and TIGS allows studying of nuclear matrix of the fruit fly (*Drosophila melanogaster*) without removing the nucleus from the embryo.
 - » This allows comparative study of nuclear matrix in different cells within the embryo, giving a boost to fruit fly genetics.

This method opens the whole field of ***Drosophila genetics*** to study nuclear organization or nuclear architecture using genetic and cell biology approaches, which has limited earlier only to biochemical approaches.

12. PRACTICE QUESTIONS

| # | Ques |
|---|--|
| 1 | <p>The production of which of the following is/are example(s) of Modern Biotechnology:</p> <ol style="list-style-type: none"> 1. Curd 2. Wine 3. Penicillin <p>Choose the correct answer from the codes given below:</p> <ol style="list-style-type: none"> A. 1 only B. 3 only C. All of the above D. None of the above |
| 2 | <p>Which of the following statements is not correct?</p> <ol style="list-style-type: none"> A. DNA is the basic physical and functional unit of heredity B. DNA is the hereditary material in humans and almost all other organisms C. Most DNA is located in the cell nucleus, but a small amount can also be found in the mitochondria D. All of the above are correct |
| 3 | Consider the following statements about DNA: |

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| | <p>1. DNA is a polymer of ribonucleotides 2. In humans, DNA is only located in the nucleus of a cell 3. The order and sequence of the base pairs on DNA determines the information available for building and maintaining an organism</p> <p>Which of the above statements is/are correct?</p> <p>A. 1 and 2 only B. 2 only C. 3 only D. 1, 2 and 3</p> |
| 4 | <p>Consider the following statements about DNA Profiling:</p> <p>1. DNA profiling is a forensic technique used to identify individuals by characteristics of their DNA 2. DNA profiling determines a gene's functionality and position in the chromosome</p> <p>Which of the above statement(s) is/are correct?</p> <p>A. 1 only B. 2 only C. Both 1 and 2 D. Neither 1 nor 2</p> |
| 5 | <p>Consider the following statements about DNA fingerprinting:</p> <p>1. DNA fingerprinting was invented in 1984 by Professor Sir Alec Jeffreys 2. He had realized that he could detect variations in human genome in the satellite DNA region</p> <p>Which of the above statements is/are correct?</p> <p>A. 1 only B. 2 only C. Both 1 and 2 D. Neither 1 nor 2</p> |
| 6 | <p>Consider the following statements about satellite DNA regions:</p> <p>1. Satellite DNA regions are stretches of repetitive DNA which don't code for any specific protein 2. Each individual (except identical twins) has a unique pattern of mini-satellites</p> <p>Which of the above statements is/are correct?</p> <p>A. 1 only B. 2 only C. Both 1 and 2 D. Neither 1 nor 2</p> |

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| | |
| 7 | <p>DNA fingerprinting can be used for which of the following purpose:</p> <ol style="list-style-type: none"> 1. Identify Individuals/dead bodies 2. Determine paternity 3. Match tissue of organ donors with those of people who need transplant 4. Identify disease which are passed through family 5. Help find cure for diseases, called hereditary diseases <p>Which of the above statements is/are correct?</p> <ol style="list-style-type: none"> A. 1, 2 and 5 only B. 3, 4 and 5 only C. 1, 2, 3 and 4 only D. 1, 2, 3, 4 and 5 |
| 8 | <p>DNA Barcoding can be used for which of the following purposes:</p> <ol style="list-style-type: none"> 1. Identify individuals within a species/ dead bodies 2. Determine paternity 3. Determining species of a living organism 4. Identifying insect larvae which may have fewer diagnostic characteristics than adults <p>Choose the correct answer from the codes provided below:</p> <ol style="list-style-type: none"> A. 1 and 2 only B. 3 and 4 only C. 1, 2 and 3 D. 1, 2, 3 and 4 |
| 9 | <p>Consider the following statements: [Prelims 2022]</p> <p>DNA Barcoding can be a tool to:</p> <ol style="list-style-type: none"> 1. Assess the age of a plant or animal. 2. Distinguish among species that look alike. 3. Identify undesirable animal or plant materials in processed foods. <p>Which of the statements given above is/are correct?</p> <ol style="list-style-type: none"> A. 1 only B. 3 only |

| | |
|----|---|
| | <p>C. 1 and 2 only</p> <p>D. 2 and 3 only</p> |
| 10 | <p>Consider the following statements about Dark DNA:</p> <ol style="list-style-type: none"> 1. The sequence of DNA which causes genetic diseases are known as dark DNA 2. These sections of DNA have not been sequenced and they don't encode any protein <p>Which of the above statements is/are correct?</p> <ul style="list-style-type: none"> A. 1 only B. 2 only C. Both 1 and 2 D. Neither 1 nor 2 |
| 11 | <p>Consider the following statements about RNA:</p> <ol style="list-style-type: none"> 1. RNA can store genetic information 2. RNAs play a crucial role in manufacture of proteins 3. RNAs generally have a much shorter chain of nucleotides than DNA <p>Which of the above statement(s) is/are correct?</p> <ul style="list-style-type: none"> A. 1 and 3 only B. 2 and 3 only C. 1 and 2 only D. 1, 2 and 3 |
| 12 | <p>Which of the following pairs is/are correctly matched?</p> <ol style="list-style-type: none"> 1. mRNA - Transfers Amino Acids to ribosomes for manufacture of protein 2. tRNA - Carries information from DNA to ribosomes for manufacture of protein 3. Ribosomes - factory of protein <p>Choose the correct answer from the codes provided below:</p> <ul style="list-style-type: none"> A. 1 and 2 only B. 3 only C. 2 and 3 only D. 1, 2 and 3 |
| 13 | <p>'RNA interference (RNAi)' technology has gained popularity in the last few years. why? (Pre 2019)</p> |

1. It is used in developing gene silencing therapies.
 2. It can be used in developing therapies for the treatment of cancer.
 3. It can be used to develop hormone replacement therapies.
 4. It can be used to produce crop plants that are resistant to virtual pathogens.

Select the correct answer using the code given below.

- (a) 1, 2 and 4
- (b) 2 and 3
- (c) 1 and 3
- (d) 1 and 4 only

14

Recombinant DNA technology (Genetic Engineering) allows genes to be transferred (Pre 2013)

1. Across different species
2. From Animals to plants
3. From microorganisms to higher organisms

Select the correct answer using the codes given below:

- a. 1 only
- b. 2 and 3 only
- c. 1 and 3 only
- d. 1, 2 and 3

15

Consider the following statements about advantages of traditional Hybridization over Genetic Modification:

1. Traditional hybridization leads to precise inclusion of genes
2. Traditional hybridization process is easy to perform

Which of the above statement(s) is/are correct?

- A. 1 only
- B. 2 only
- C. Both 1 and 2
- D. Neither 1 nor 2

16

With reference to the recent developments in science which one of the following statements is not correct? (Pre 2019)

- (a) Functional chromosomes can be created by joining segments of DNA taken from cells of different species
- (b) Pieces of artificial functional DNA can be created in laboratories.
- (c) A piece of DNA taken out from an animal cell can be made to replicate outside a living cell in a laboratory.

| | (d) Cells taken out from plants and animals can be made to undergo cell division in laboratory petri dishes. | | | | |
|------------------------------|---|------------------------------|---------------|------------------------|-------------------------|
| 17 | <p>In the context of the development in Bio-informatics, the term 'Transcriptome', sometimes seen in the news, refer to: (Pre 2016)</p> <ol style="list-style-type: none"> A range of enzymes used in genome editing The full range of mRNA molecules expressed by an organism The description of the mechanism of gene expression A mechanism of genetic mutations taking place in cells | | | | |
| 18 | <p>Consider the following statements from CRISPR-CAS9:</p> <ol style="list-style-type: none"> It's a genome editing tool which is simpler, faster, more versatile and cheaper than other prominent genome editing tool The tool is inspired from the mechanisms used by various bacterias to fight various bacteriophage The 2022 Nobel Prize for Physics was given to two scientists who developed CRISPR-Cas9 <p>Which of the above statements are correct?</p> <ol style="list-style-type: none"> 1 and 2 only 2 and 3 only 1 and 3 only 1, 2 and 3 | | | | |
| 19 | <p>Consider the following statements about various developments using CRISPR-CAS9:</p> <ol style="list-style-type: none"> So far, CRISPR-Cas9 hasn't shown any success in curing genetic diseases Indian government has approved a five year project to develop CRISPR to cure sickle cell Anaemia CRISPR has already been used for developing improved variety of agricultural crops like tomatoes <p>Which of the above statements are correct?</p> <ol style="list-style-type: none"> 1 and 2 only 2 and 3 only 1 and 3 only 1, 2 and 3 | | | | |
| 20 | <p>Consider the following pairs:</p> <table border="1"> <thead> <tr> <th>Terms sometimes seen in news</th> <th>Context/Topic</th> </tr> </thead> <tbody> <tr> <td>i. Belle II Experiment</td> <td>Artificial intelligence</td> </tr> </tbody> </table> | Terms sometimes seen in news | Context/Topic | i. Belle II Experiment | Artificial intelligence |
| Terms sometimes seen in news | Context/Topic | | | | |
| i. Belle II Experiment | Artificial intelligence | | | | |

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|------|--------------------------|-------------------------|
| ii. | Blockchain Technology | Digital/ Cryptocurrency |
| iii. | CRISPR – Cas9 | Particle Physics |

Which of the pairs given above are correctly matched? (Pre 2018)

- A. 1 and 3 only
- B. 2 only
- C. 2 and 3 only
- D. 1, 2 and 3 only

21

What is cas9 protein that is often mentioned in news ? (Pre 2019)

- (a) A molecular scissors used in targeted gene editing
- (b) A biosensor used in the accurate detection of pathogens in patients.
- (c) A gene that makes plants pest-resistant
- (d) A herbicidal substance synthesized in generally modified crops

22

Consider the following statements about T-cells:

- 1. T cells are a type of white blood cells
- 2. They are formed from hematopoietic stem cells
- 3. They are also called thymocytes
- 4. Mutations in T-cell genes may lead to T cells turning against the body and ending up destroying health cells

Which of the above statements is/are correct?

- A. 1 only
- B. 2 only
- C. 2 and 3 only
- D. 1, 2, 3 and 4

23

Which of the following statements best describe the role of B Cells and T Cells in the human body?

- A. They protect the body from environment allergens
- B. They alleviate the body's pain and inflammation
- C. They act as immunosuppressants in the body
- D. They protect the body form the diseases caused by Pathogens

24

What is the application of Somatic Cell CJ Nuclear Transfer Technology? (Pre 2016)

- a. Production of bio larvicides
- b. Manufacture of biodegradable plastics
- c. Reproductive cloning of animals

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| | d. Production of organisms free of diseases |
| 25 | <p><i>At present, scientists can determine the arrangement or relative positions of genes or DNA sequences on a chromosome. How does this knowledge benefit us? (2011 Pre)</i></p> <ol style="list-style-type: none"> 1. It is possible to know pedigree of livestock 2. It is possible to understand the causes of all human diseases 3. It is possible to develop disease-resistant animal breeds <p>Which of the statements given above are correct?</p> <ol style="list-style-type: none"> a. 1 and 2 only b. 2 only c. 1 and 3 only d. 1, 2 and 3 only |
| 26 | <p>Consider the following statements about genetic mutations:</p> <ol style="list-style-type: none"> 1. All genetic mutations are functional. 2. A number of recombinant lineages of SARS-CoV-2 have been observed during the Covid-19 Pandemic <p>Which of the above statements is/are correct?</p> <ol style="list-style-type: none"> A. 1 only B. 2 only C. Both 1 and 2 D. Neither 1 nor 2 |
| Biotechnology in Agriculture | |
| 27 | <p>With reference to the Genetically modified mustard (GM mustard) developed in India, consider the following statements (Prelims 2018)</p> <ol style="list-style-type: none"> 1. GM Mustard has the genes of a soil bacterium that give the plant the property of pest resistance to a wide variety of pests 2. GM Mustard has the genes that allow the plant cross-pollination and hybridization 3. GM Mustard has been developed jointly by IARI and Punjab Agricultural University <p>Which of the statements given above is/are correct?</p> <ol style="list-style-type: none"> a. 1 and 3 only b. 2 only c. 2 and 3 only d. 1, 2 and 3 only |

28

What are the reasons for the people's resistance to the introduction of Bt brinjal in India (2011)

1. Bt Brinjal has been created by inserting a gene from a soil fungus into its genome
2. The seeds of Bt brinjal are terminator seeds and therefore, the farmers have to buy the seeds before every season from the seed companies
3. There is an apprehension that the consumption of Bt Brinjal may have adverse impact on health
4. There is some concern that the introduction of Bt brinjal may have adverse effect on the biodiversity

Select the correct answer using the codes given below:

- a. 1, 2 and 3 only
- b. 2 and 3 only
- c. 3 and 4 only
- d. 1, 2, 3 and 4

29

Other than resistance to pests, what are the prospects for which genetically engineered plants have been created? (Prelims 2011)

1. To enable them to withstand drought
2. To increase the nutritive value of the produce
3. To enable them to grow and do photosynthesis in spaceships and space and space stations
4. To increase their shelf life

Choose the correct answer from the codes provided below:

- A. 1 and 2 only
- B. 3 and 4 only
- C. 1, 2 and 4 only
- D. 1, 2, 3 and 4

30

With reference to agriculture in India, how can the technique of genome sequencing, often seen in the news, be used in the immediate future

1. Genome Sequencing can be used to identify genetic markers for disease resistance and drought tolerance in various crops
2. This technique helps in reducing the time required to develop new varieties of crops plants
3. It can be used to decipher the host-pathogen relationship in crop

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| | <p>Select the correct answer using the code given below:</p> <ul style="list-style-type: none"> a. 1 only b. 2 and 3 only c. 1 and 3 only d. 1,2 and 3 |
| 31 | <p>Consider the following statements about Golden Rice:</p> <ol style="list-style-type: none"> 1. Golden rice is a GM rice variety that has been developed by Indian Council for Agricultural Research 2. India has become the first country to cultivate golden rice 3. GM Modification has led to increased percentage of protein in the Golden rice <p>Which of the above statements is/are correct?</p> <ul style="list-style-type: none"> A. 3 only B. 1 and 2 only C. 1, 2 and 3 D. None of the above |
| 32 | <p>Consider the following statements about BT Brinjal:</p> <ol style="list-style-type: none"> 1. It is a genetically modified Brinjal type which was created by adding genes from soil fungus 2. It has not been approved by Genetic Engineering Appraisal Committee under the Ministry of Environment Forest and Climate Change (MoEF&CC) 3. It has resistance against insects like Brinjal Fruit and Shoot Borer (BFSB) <p>Which of the above statement(s) is/are correct?</p> <ul style="list-style-type: none"> A. 1 and 2 only B. 2 only C. 3 only D. 1 and 3 only |
| 33 | <p>Consider the following statements about Genetic Engineering Appraisal Committee:</p> <ol style="list-style-type: none"> 1. It is the final approving authority for allowing commercial use of genetically modified food crop in India 2. It is an autonomous body working under Ministry of Science and Technology, Government of India <p>Which of the above statements is/are correct?</p> <ul style="list-style-type: none"> A. 1 only B. 2 only C. Both 1 and 2 |

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| | D. Neither 1 nor 2 |
| | |
| 34 | <p>"Rht13: was in news recently, it refers to:</p> <ul style="list-style-type: none"> A. A new variety of rice with higher vitamin-A developed recently B. A dwarfing gene in wheat C. A new organically produced pesticide D. None of the above |
| 35 | <p>Reduced Height Gene (Rht) have increased global yields of wheat because:</p> <ol style="list-style-type: none"> 1. The short stemmed wheat puts more investment into the grains 2. It leads to reduced risk of lodging 3. It increases the partitioning and assimilation of grains <p>Choose the correct answer from the codes provided below:</p> <ul style="list-style-type: none"> A. 1 only B. 2 and 3 only C. 1 and 3 only D. 1, 2 and 3 |
| 36 | <p>Consider the following statements :</p> <ol style="list-style-type: none"> 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. <p>Which of the statements given above is/are correct ?</p> <ul style="list-style-type: none"> a) 1 only b) 2 and 3 only c) 2 only d) 1, 2 and 3 |
| 37 | <p>Which of the following COVID-19 vaccines (type) pairs is/are correctly matched?</p> <ol style="list-style-type: none"> 1. Covaxin (mRNA vaccine) 2. Covishield (weakened/inactivated virus vaccine) 3. Corbevax (protein subunit vaccine) 4. Soberana 02 (Conjugate vaccine) <p>Choose the correct answer from the codes provided below:</p> <ul style="list-style-type: none"> A. 1 and 2 only B. 3 and 4 only C. 1 only D. None of the above |

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| 38 | <p>Consider the following statements about Gene Therapy in India:</p> <ol style="list-style-type: none"> 1. Gene therapy products are not available in India so far. 2. Recently, Medical Council of India has released guidelines for Gene Therapy Product development and clinical trials 3. These guidelines are aimed at ensuring that gene therapies are introduced in India and clinical trials for gene therapy can be performed in an ethical, scientific and safe manner <p>Which of the above statement(s) is/are correct?</p> <ol style="list-style-type: none"> A. 1 and 2 only B. 1 and 3 only C. 2 and 3 only D. 1, 2 and 3 |
| 39 | <p>Consider the following statements about Haemophilia B disease:</p> <ol style="list-style-type: none"> 1. It is a hereditary blood disorder 2. It is also called factor VIII (8) deficiency or classic haemophilia 3. Pfizer has recently tested fidanacogene elaparvovec, an investigational gene therapy, for the treatment of adult males with moderately severe to severe haemophilia B <p>Which of the above statements are correct?</p> <ol style="list-style-type: none"> A. 1 and 2 only B. 2 and 3 only C. 1 and 3 only D. 1, 2 and 3 |
| 40 | <p>Consider the following statement(s) about Polymerase Chain Reaction (PCR):</p> <ol style="list-style-type: none"> 1. PCR can be used in detection of HIV in suspected AIDS patient 2. It works on the principle of antigen-antibody interaction <p>Choose the correct answer from the codes provided below:</p> <ol style="list-style-type: none"> A. 1 only B. 2 only C. Both 1 and 2 D. Neither 1 nor 2 |
| 41 | <p>National Guidelines for Gene Therapy Product Development and Clinical Trials were released by which of the following bodies? Choose the most appropriate answer:</p> <ol style="list-style-type: none"> a. Department of Science and Technology b. Indian Council for Medical Research c. Ministry of Environment Forest and Climate Change d. Department of Biotechnology |
| 42 | <p>eDNA (or Environmental DNA) based assay can be used for:</p> |

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| | <p>1. Detecting invasive fish species in waterbodies 2. Understanding the species of the pollen 3. Knowing the age of a plant</p> <p>Which of the above statements is/are correct?</p> <p>A. 1 only B. 3 only C. 1 and 2 only D. 2 and 3 only</p> |
| 43 | <p>Which of the following is/are not true about the stem cells:</p> <p>1. Stem cells are only found in Embryonic stage 2. Some specialized cells can be converted into stem cells by modifying them genetically 3. Stem cells can be used to repair and regenerate tissues but whole organs can't be developed from them</p> <p>Choose the most appropriate answer from the codes provided below:</p> <p>A. 1 only B. 1 and 2 only C. 1 and 3 only D. 2 and 3 only</p> |
| 44 | <p>Consider the following statements about Controlled Human Infection Model (CHIM) Study:</p> <p>1. CHIM studies can ensure increased local relevance of medicines in India 2. Government of India has recently allowed the use of CHIM studies for drug testing</p> <p>Choose the correct answer from the codes provided below:</p> <p>A. 1 only B. 2 only C. Both 1 and 2 D. Neither 1 nor 2</p> |
| 45 | <p>Which of the following correctly define Nuclear Matrix?</p> <p>A. A scaffolding that helps package genome differently in different types of cells B. A region within a prokaryotic cell that contains most or all of the genetic material C. It is the largest nuclear organelle and is primary site of ribosome subunit biogenesis in eukaryotic cells D. A thick solution that fills each cell and is enclosed by the cell membrane</p> |