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T-303, 3rd Floor
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Preface

If you ever happen to be walking down the streets of places where preparation for Civil Services is done, it will not be uncommon for you to come across or make the acquaintance of 'several' starry eyed yet completely committed IAS aspirants. Yet, 'several' would be an understatement given the number that runs into lakhs! But when we say committed, we mean it; these young men and women are ready to sacrifice almost all their youthful follows, including sleep, comfort, and even a semblance of a normal life to achieve one goal—IAS!

Sadly, this dream remains a distant one for a large majority of these aspirants in spite of the endless hours of study and sleep forsaken nights. When we tried to unravel WHY the responses were almost synchronous:

"The subject was so vast that there was too much to cover, and I could never complete it."

"I read so much but could not retain it."

"I studied something but was quizzed on something else in the exam."

"I kept reading but did not attempt to solve the past years' papers or give a mock exam."

"Subscribing to several sources of information/preparation, such as a coaching class, the internet and books, was futile; after all, there are only 24 hours in a day."

"My almirah was full of too many books, but I could barely complete a few."

And while the candid answers stated above clearly gave us a challenging problem—we did not attempt to solve it. We instead focused on a holistic solution—the synchronizing of effort, i.e., Learning and Positive Results!

With this aim, we—PrepMate collaborated with Cengage India—are continuously striving to develop a comprehensive learning model that is a combination of print and digital product to effectively address the issues that most aspirants grapple with.

About the Print–digital Learning Model

The learning model initiates the process with a series of books targeted at cracking the UPSC exam. The books stand apart from others available because of the following unique features:

- We use a conceptual approach, simple language, explain concepts with diagrams, cite sufficient examples, pose pertinent questions in a reader, friendly format—to ensure that the contents of these books can be read and assimilated in a time-bound manner.
- The content is specially designed, taking into account the trend in UPSC exams in recent years. We have also included the previous years' questions (with solutions) after every chapter.

- The Practice Questions at the end of each chapter are exhaustive to provide sufficient preparation to crack the exams.
- We have tried to encapsulate all that is required to be learnt for a particular subject into a single book.

Usually, an aspirant purchases a book but never gets a chance to contact the authors. We believe that the contact among aspirants and authors is important for learning and motivation of the aspirants. That is precisely why we have developed an application and a web portal to answer your queries and provide you with continuous support during your preparation.

It is through this digital component that we provide the following services:

1. Videos covering important and difficult topics
2. Daily prelims quiz
3. Assistance in interview preparation
4. Regular updates
5. Daily current affairs
6. Monthly current affairs magazine
7. Radio news analysis
8. Educational videos
9. Previous years' papers and solutions
10. Free study materials

Looking forward to being your partner in the journey towards achieving your dream!

In case you have any specific queries or constructive feedback you can always share the same with us via e-mail at info@prepmate.in.

PrepMate

Acknowledgements

"We cannot accomplish all that we want to do without working together"

The complete UPSC learning module by Prepmate has been the culmination of more than a year of ideation and brain storming with a lot of people. It is only natural that we should gratefully acknowledge their valuable contribution sincerely. Nirmal Singla, Ramnik Jindal, Sharat Gupta, Subhash Singla, and Vijay Singla—thank you for your continuous support and motivation.

We would also like to thank Maninder Mann, Rajinder Paul Singla, and Sundeep Singh Garha, who helped us in first conceiving and later developing the synergistic print–digital model of the project—without you we would be missing our competitive edge.

The development of the digital component did prove to be tougher than we had envisaged. But our technical team was focused on enabling our dream and delivering the best, and they surely did. With a specific mention to the testing of both the website and the application,we would like to thank Parth, Tanvir, and Surabhi, who did their job patiently and effectively in spite of the road blocks.

Our videos and books could not have been possible without the help of our graphics design team—Sandeep, Manjeet, Sukhjinder, Roshni, and Uday toiled endlessly to ensure the best designed audio-visuals.

It is an understatement that the sourcing and reviewing of existing content and the generation of missing content was the most crucial part of this project and the backbone of our Learning Module. This would just not have been possible without our team of content contributors: Isha Gupta, Shelly Jindal, Gurdeep, Surabhi, Shantnu, Tanvir, Anmol, Kriti, Tanya, Sahil, Suraj, and Dilshad, who left no stone unturned in their pursuit of excellence—your pivotal contributions are gratefully acknowledged.

We would like to extend a special thanks to our staff members Geeta, Jitender, Manoj, and Pinki, who helped us in the most laborious job, i.e., typing through the several manuscripts of our books—your contribution is sincerely appreciated.

It is imperative that we thank Isha Gupta, Shelly Jindal, Anjum Diwan, Rajesh Goel, Shikha Sharma, and Ravinder Indoura, for their critical yet constructive feedback that identified and subsequently rectified the errors that crept in during the development process. We will never be able to thank them enough for this—you fortified the very foundation of our model.

We sincerely acknowledge the initiatives and support from the entire editorial team of Cengage India in the process of publishing this book.

PrepMate

List of Videos

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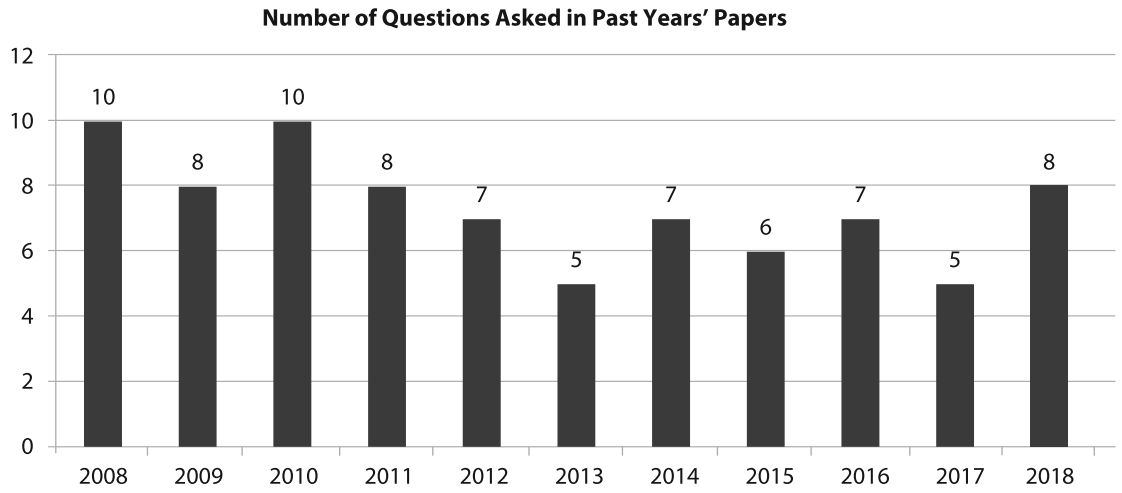
4.	Satellite Orbit
5.	Fracking
6.	Electromagnetic Spectrum
7.	Meissner Effect
8.	Nanotechnology
9.	Large Hadron Collider
10.	Internet of Things

Chapter-wise Break Up of Previous Year's Questions (Prelims)

Chapter	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	Total
1. Biotechnology	1	2	1	2	1	1	1	2	3	1	2	17
2. Nuclear Research					1				1	1		3
3. Space Research		1	3		2	1	1			2	2	12
4. Defence							1					1
5. Sources of Energy	1				1	1	2	2	1	1	2	11
6. Laser										1		1
7. Electromagnetic Radiation									1		2	3
8. Superconductors												
9. Nanotechnology	1					1	1					3
10. Advancement in Fundamental Physics	1	1		2		1		1	1		1	8
11. Information Technology	1	1	1		1					1		5
12. Advances in Information Technology	1	1	3		1							6
13. Communication Technology	1	1			1	1				1	1	6
14. Lighting Systems				1								1
15. Robotics												
16. Artificial Intelligence	1											1
17. Payment Technologies			2	2	1							5
18. Artificial Reality		1										1
19. Climate Technologies				1								1
20. Water purification technologies												
21. Transportation Technologies	1											1
22. Data Security	1	1										2
23. Miscellaneous		1					1					2
Total	10	10	10	8	9	6	7	5	7	8	10	90


Number of Questions Asked in Past Years' Papers
12
10
8
6
4
2
0
10
8
10
8
7
5
7
6
7
5
8
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

CHAPTER

1 Biotechnology

1 BIOTECHNOLOGY

The word 'biotechnology' is made up of two words: 'bio' and 'technology'. 'Bio' means life, and 'technology' means applying or harnessing of science for a specific purpose. Therefore, the term 'biotechnology' refers to the modification or use of any living organism for any useful purpose.

The term 'biotechnology' is largely believed to have been coined in 1919 by the Hungarian engineer, Károly Ereky. In the late twentieth and early twenty-first centuries, biotechnology has expanded to include new and diverse sciences, which we will discuss in this chapter. Even after so many advances, the Recombinant DNA Technology forms the basis of biotechnology. Let us first understand this technology.

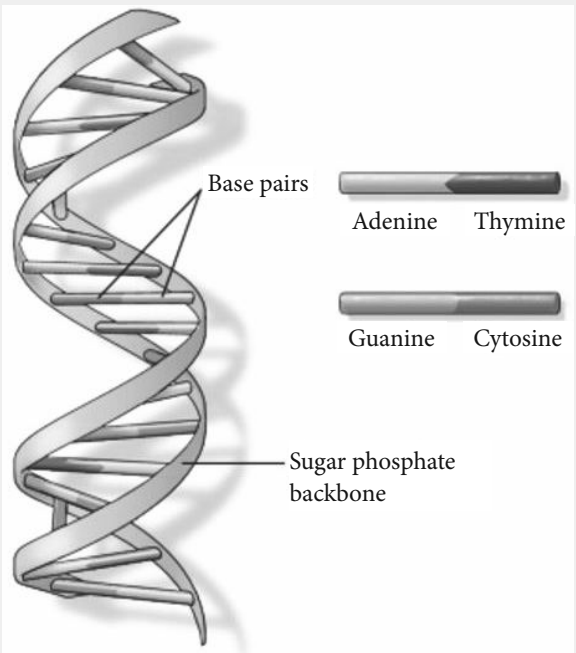
2 RECOMBINANT DNA TECHNOLOGY

The recombinant DNA technology is a technology through which a foreign gene of an organism is inserted into a host organism to produce desired qualities in the host organism. Such a foreign gene may be acquired even from an organism that is unrelated to the host organism.

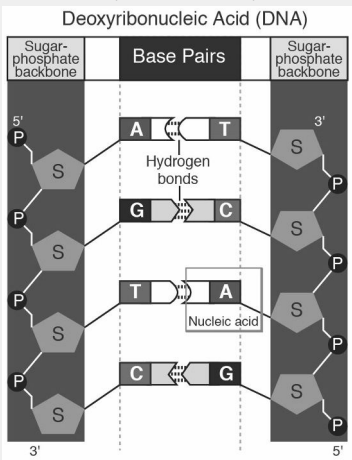
What Is DNA?

Deoxyribonucleic acid (DNA) is the genetic material typically found in all living cells of humans as well as animals and plants. It contains hereditary data passed on from parents to their children, which is unique to each person (except in the case of identical twins). DNA is a double helix structure (helix structure means shape of spiral staircase) and consists of base pairs formed from four bases- adenine (A), guanine (G), cytosine (C), and thymine (T).

Each base is attached to a sugar phosphate backbone (structure formed from phosphate and a sugar molecule). A sugar molecule, phosphate molecule, and a base together form a nucleotide. The nucleotides are arranged in two long strands to form a double helix structure, as shown in the figure.



When the base pairs are formed, the bonding between the bases causes the DNA strands to spiral around each other, forming a double helix shape. Each base pair is made up of two bases. Adenine always pairs with Thymine, and Cytosine always pairs with Guanine to form a base pair.



DNA has the capability to replicate itself. It follows the pattern in a DNA strand to create identical DNA. In other words, DNA replicates by duplicating the sequence of bases.

DNA and RNA

DNA, or deoxyribonucleic acid, is like a genetic blueprint of guidelines that a living organism must follow to exist and remain functional. RNA, or ribonucleic acid, helps carry out this blueprint's guidelines. It is complementary to DNA, helping carry out the tasks encoded in DNA.

DNA is more stable and holds more complex information for longer periods of time. On the other hand, RNA is more flexible and capable of performing different tasks. DNA is found in the nucleus of a cell (nuclear DNA) and mitochondria (mitochondrial DNA). Mitochondria is the part of the cell responsible for generation of energy. It has a fixed double helix structure. The RNA does not have a fixed location in a cell and adopts different structures depending on the role it is to play—as messenger RNA (mRNA), transfer RNA (tRNA), or ribosomal RNA (rRNA).

Messenger RNA (mRNA): Messenger RNA (mRNA) transcribes genetic information from the DNA found in a cell's nucleus and then carries this information to other cell organelles, specifically ribosome (site of protein manufacture). The full range of messenger RNA, or mRNA, molecules expressed by an organism is transcriptome. An organism's transcriptome varies depending on many factors, including the stage of development and environmental conditions. In contrast with the genome, which is characterised by its stability, the transcriptome actively changes.

Transfer RNA (tRNA): Transfer RNA (tRNA) is found in a cell's cytoplasm (fluid that fills the inside of the cell and surrounds all the cell organelles) and is closely related to mRNA as its helper. tRNA transfers amino acids, the core components of proteins, to the mRNA in a ribosome.

Ribosomal RNA (rRNA): Ribosomal RNA (rRNA) is also found in a cell's cytoplasm. In the ribosome, it takes mRNA and tRNA and translates the information they provide. From this information, it 'learns' whether it should create protein.

DNA genes are expressed or manifested through the proteins which are produced with the help of RNA. Traits (phenotypes) come from which proteins are made and which are switched on or off. The information found in DNA determines which traits are to be created, activated, or deactivated, while the various forms of RNA do the work.

Steps in rDNA Technology

The following are the basic steps involved in Recombinant DNA technology:

1. Insert is isolated. The DNA fragment that contains the gene of interest and needs to be inserted into a host organism is called the Insert.
2. This DNA fragment is inserted into a carrier DNA molecule and a recombinant DNA molecule is thus generated. The carrier DNA molecule is called the vector. The rDNA thus generated has the ability to self-replicate within a host cell.
3. The third step involves a process called transformation. In this, the rDNA generated in the earlier step is transferred into an E. coli (Escherichia coli) bacteria host cell.

4. The host cells carrying the rDNA are selectively allowed to multiply. This trend generates more rDNA molecules.

This leads to generation of a large amount of rDNA, and hence, gene cloning is achieved. To successfully carry out the process, we need an insert and vector and a method to precisely cut and join the DNA molecules. The joining of the DNA molecules together is called ligation.

Tools Used in rDNA Technology

The tools generally used in rDNA technology are as follows:

Restriction Enzymes: Restriction enzymes act as the molecular scissors. In other words, these enzymes can be used to precisely cut a DNA molecule at the required location. These enzymes are derived from bacteria. In bacteria, these enzymes are naturally present as part of its defense mechanism called the Restriction-Modification System. These restriction (restriction endonucleases) and modification enzymes (methylases) are unique to each bacterial species.

Restriction-modification System

The Restriction-Modification System in bacteria consists of two components: a restriction enzyme and a modification enzyme.

The restriction enzyme selectively recognises a particular sequence of DNA. Once it recognises such a sequence in a DNA, it digests the DNA fragment containing that sequence. In other words, it restricts that particular sequence of DNA from propagation by digesting the DNA fragment. This helps the bacteria to protect itself from any foreign DNA (such as virus).

The modification enzyme, on the other hand, recognises a particular sequence and adds a methyl group to one or two bases in the DNA sequence. This is called methylation. A methyl group is derived from methane, containing one carbon atom bonded to three hydrogen atoms— CH_3.

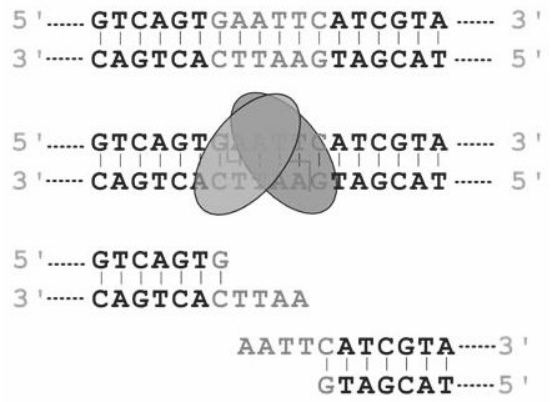
Once methylation is done, that particular sequence cannot be digested by the bacteria. This enzyme adds methyl group only to Bacteria's own DNA and excludes foreign DNA from methylation. As the foreign DNA is not protected by methylation, it can be easily digested. In simple terms, the modification enzyme selectively protects a Bacteria's DNA and leaves foreign DNA, which is then digested by the restriction enzyme.

Each species of bacteria have their own set of restriction-modification enzymes. The three main classes of restriction endonucleases are named type I, type II, and type III. Of these three types, only type II restriction enzymes are used in rDNA technology as they can be used to recognise and cut the DNA in the required specific sequence.

These type II enzymes are sourced from different microbial sources. The genetic engineers choose a particular enzyme based on the requirement (i.e., the location where the DNA needs to be cut). There are more than a thousand restriction enzymes available at present, from which a restricted enzyme can be chosen.

The Type II restriction enzymes are named after the bacterial species from which they are isolated. EcoRI, which is isolated from the E.coli bacteria, is the most commonly used restriction enzyme. As the name indicates, E stands for the genus, co stands for the species, and 'R' refers to the strain RY 13. The roman numeral 'I' indicates that this is the first enzyme to be isolated from this strain of bacteria.

Some of the restriction enzymes (Type II) and their sources are given in the table below after the diagram. The location at which a restriction enzyme can cut the DNA is indicated by the arrow symbols in the recognition sequence. Any DNA that matches this recognition sequence (DNA in which base pairs are similarly arranged) will be digested by the restriction enzyme of the bacteria. For instance, EcoRI cuts the GAATTC sequence, as shown in the figure. The enzyme is shown in grey colour and oval shape.



Restriction enzyme	Microbial source	Recognition sequence
Alu I	Arthrobacter luteus	↓ 5'A-G-C-T 3' 3'T-C-G-A 5' ↑
BamHI	Bacillus amyloliquefaciens	↓ 5'G-G-A-T-C-C 3' 3'C-C-T-A-G-G 5' ↑
EcoRI	Escherichia coli	↓ 5'G-A-A-T-T-C 3' 3'C-T-T-A-A-G 5' ↑
EcoRII	Escherichia coli	↓ 5'C-C-T-G-G 3' 3'G-G-A-C-C 5' ↑

What Are 5′ and 3′ in a DNA Sequence?

The DNA direction is indicated by using 5' and 3' which are called "five prime" and "three prime". These numbers indicate the location of a phosphate group (phosphate group is attached to 5' carbon) and the hydroxyl group (attached to 3' carbon) attached to the sugar molecule. In other words, 5' and 3' are used to indicate how the base pairs are arranged in a DNA strand. They are written in a 5'- 3' pattern as DNA synthesis always happens from 5' to 3'.

DNA ligase: DNA Ligase is another enzyme that plays an important role in the rDNA technology. It is used to connect two strands of DNA together by forming a covalent bond between the two. The phosphate group on one DNA strand is connected with the deoxyribose group on the other DNA strand. Deoxyribose is the five-carbon sugar molecule that helps form the phosphate backbone of DNA molecules. The bonds that are formed as a result are called the phosphodiester bonds. One of the most frequently used DNA ligases is isolated from the bacteriophage T4 (bacteriophages are viruses that infect bacterial cells).

Alkaline phosphatase: Generally, in ligation, a 5'phosphate group of one strand joins with the other strand containing a 3'hydroxyl group. The presence of a phosphate group is essential to carry out ligation. In some cases, the same DNA fragments' phosphate group may join with its own hydroxyl group. This is called self-ligation, which needs to be avoided to generate the required rDNA. Hence, the DNA fragments are treated with an enzyme called alkaline phosphatase. This removes the phosphate groups from the DNA fragments. This ensures that the fragments cannot ligate within themselves and are forced to ligate with other fragments containing the 5'phospahte groups.

Vectors: Vectors are DNA molecules that serve as a vehicle to carry the required foreign DNA sequence into a host cell. The vector must contain an origin of replication (a particular sequence in a DNA molecule at which replication is initiated) so that it can replicate independently within the host. This ensures that the foreign insert carried by the vector is automatically replicated. Along with this, a vector should also have a selectable marker. Selectable marker is a gene that is used to identify the host cells containing the vector.

The procedure that involves transformation of cells using rDNA technology is around 1% efficient. We need to identify the cells where the procedure is successful and isolate them. Selectable markers are used to identify these cells.

For instance, genes that confer antibiotic resistance and enzymes such as β-galactosidase can turn the substrates blue in the host cell colony. Similarly, a gene that has Green Fluorescent Protein exhibits green fluorescence when viewed under UV light. Let's consider that we have used such a vector to make the required rDNA. To check whether the multiplication of the required genes is successful, we can observe the host cells under UV light. If we find more genes exhibiting fluorescence, this means the presence of the vector DNA has increased, which indicates that the multiplication of the foreign DNA is successful. Using selective markers, the transformed cells can be easily identified. These transformed cells can then be selected for growth and division.

3 APPLICATIONS OF BIOTECHNOLOGY

Green Biotechnology

The use of biotechnology in the field of agriculture is called green biotechnology. One of the important applications under green biotechnology is the development of transgenic plants.

What are transgenic plants? In a transgenic crop plant, one or more genes are artificially inserted instead of the plant acquiring such genes through pollination. The inserted gene sequence (transgene) may come either from another unrelated plant or from a completely different species. Plants containing transgenes are often called genetically modified (GM)crops.

For instance, *Bacillus thuringiensis* (Bt) cotton is a transgenic crop developed with the help of particular genetic engineering technology popularly known as Bollgard technology. In the Bollgard-I technology, 'Cry1Ac' gene of Bt is introduced to make the crop pest-resistant. After the introduction of this gene, the cotton crop starts producing its own pesticide. The Bt trait has been believed to save the cotton plant from the pest, which is popularly known as 'ball worm'. Bollgard-II technology is a superior double-gene technology—Cry1Ac and Cry 2Ab, which provide protection against bollworms and Spodoptera caterpillar, respectively, are introduced to the cotton plant.

Bacillus thuringiensis (Bt) is a soil-dwelling bacterium, commonly used as a biological pesticide. It also occurs naturally in the gut of moths and butterflies, on leaf surfaces, etc. It is deliberately used in flour mills and in grain-storage facilities.

Why should we make transgenic crop plants? A plant breeder tries to accumulate a combination of genes in a crop plant so as to make it useful and more productive as far as possible.

Desirable genes may provide the following features:

1. **Increased crop production:** Transgenic plants, which have been developed to produce higher yields, are tolerant to diseases, drought, etc., such crop attributes have facilitated increased crop production.
2. **Improved nutritional value:** Transgenic plants with higher nutritional value have been produced. For instance, golden rice is a transgenic variety of rice, with genes for the synthesis of beta-carotene (β-carotene) taken from daffodil plant and inserted into rice. The β-carotene is converted into vitamin A. Thus, golden rice helps in preventing nutritional blindness in people, which occurs due to the deficiency of vitamin A, and is also responsible for the normal functioning of the immune system. The golden rice is called so because the rice grain is pale yellow in colour, instead of pearly white. The colour is due to the presence of β-carotene.
3. **Increased shelf life:** Transgenic plants have been developed with longer shelf life, making storage and transportation easier.
4. **Environmental benefits:** Transgenic varieties rely on reduced consumption of pesticides. Consequently, there is fewer pesticide residues in foods, reduction of pesticide leaching into groundwater, and minimization of the farm worker's exposure to hazardous products.

Comparison with traditional plant breeding Traditional plant breeding has been limited to artificially crossing plants within the same species or closely related species to bring different genes together through selective or mutation breeding techniques. For example, a gene for protein in soya bean could not be transferred to a completely different crop such as wheat using traditional techniques.

Transgenic technology enables plant breeders to bring useful genes together in one plant from a wide range of living sources. Thus, it expands the possibilities beyond the limitations imposed by traditional cross-pollination and selection techniques.

How are transgenic plants developed? Transgenic plants are the plants that have been genetically engineered, a breeding approach that uses recombinant DNA techniques to create plants with desired characteristics. Genetic engineering is the process by which scientists modify the genome (the complete set of genes or genetic material present in a cell or organism) of an organism. The creation of genetically modified organisms requires recombinant DNA.

This technology provides the means for identifying and isolating the genes controlling specific characteristics in one kind of organism and for moving copies of those genes into another different organism, which will also have those characteristics. This powerful tool enables the plant breeders to generate more useful and productive crop and animal varieties containing new combinations of genes.

In other words, transgenic plants are obtained through recombinant DNA technology or genetic engineering. Recombinant DNA technology is a technology through which a foreign gene of an organism is inserted into a host organism to produce desired qualities in the host organism. Such a foreign gene may be acquired even from an organism that is unrelated to the host organism.

Pest Resistant Plants: Green Biotechnology is also used for the development of pest-resistant plants. For instance, a process called RNA interference (RNAi) was used to develop a pest resistant tobacco plant. In this process, a specific mRNA (messenger RNA) is prevented from undergoing translation (translation is a process of creating proteins from messenger RNA or mRNA). RNA interference can also be induced experimentally by using a double stranded RNA molecule. The double stranded RNA molecule binds to the specific mRNA, and hence prevents its translation. This is called silencing of mRNA. This technique was used to develop a pest resistant tobacco plant.

A nematode (roundworm) known as Meloidegyne incognitia infects the roots of tobacco plants, thereby causing a reduction in the yield. Nematode-specific genes introduced into the host plant produce a double stranded RNA (dsRNA) that initiates RNAi. The dsRNA binds to the mRNA of the pest and silences it. As a result, the pest cannot survive in the host plant. In other words, the pest resistant tobacco plant is developed in such a way that the parasite could not survive in these tobacco plants.

Red Biotechnology

The use of biotechnology in the field of medicine is called red biotechnology. Red biotechnology is used in the following medical processes:

1. **Gene therapy:** It is a subdivision of red biotechnology that deals with the diagnosis and treatment of genetic diseases and other diseases that are related to genetic makeup of an individual. Modern life science considers genetic makeup important in diseases even associated with heart or cancer. In gene

therapy, the treatment revolves around the manipulation or replacement of defective genes. It may also involve insertion of missing genes.

2. **Pharmacogenomics:** This field is a combination of genetics and pharmaceuticals. Pharmacogenomics analyses how genetic makeup affects an individual's response to drugs. It deals with the influence of genetic variation of drug response in patients by correlating gene expression with the efficacy or toxicity of a drug.

   Pharmacogenomics offers new possibilities in the design and production of drugs and how they can be adapted to each individual and their genetic makeup. Specifically, applications in pharmacogenomics have resulted in the development of custom drugs, accurate dosages for different individuals, etc.

3. **Genetic testing (or genetic screening):** Genetic testing allows diagnosis of genetic vulnerabilities leading to inherited diseases and can also be used to determine a child's parentage (genetic mother and father) or in general, a person's ancestry.

   Genetic testing, in a broader sense, includes biochemical tests for the possible presence of genetic diseases or changes that are associated with inherited disorders, or mutant forms of genes associated with increased risk of developing genetic disorders. Since genetic testing revelations may lead to psychological problems, genetic testing is often accompanied by genetic counselling.

4. **Drug administration:** Biotechnology has contributed to the discovery and manufacturing of pharmaceutical drugs as well as drugs that are the product of biotechnology, which are called biopharmaceutics.

   Biopharmaceutics examines the interrelationship of the physical/chemical properties of the drug, the dosage form (drug product), and the manner of drug administration on the rate and extent of drug absorption. Thus, biopharmaceutics has helped in enhancing the therapeutic effect of a drug.

   Biotechnology has also helped in the field of **pharmacokinetics**. It is described as what the body does to a drug, refers to the movement of drug into, through, and out of the body—the time course from its absorption to excretion.

5. **Virotherapy:** It is a medical treatment that uses biotechnology to convert viruses into therapeutic agents. The viruses are genetically modified to treat diseases. There are three main branches of virotherapy: anti-cancer oncolytic viruses, viral vectors for gene therapy, and viral immunotherapy.

6. **Molecular Diagnosis:** Molecular diagnosis refers to the process of identifying a disease by studying molecules such as DNA, RNA, and proteins in a tissue. Molecular diagnosis helps in early detection of disease, even before the symptoms have appeared. Early diagnosis of disease is essential for effective treatment of a disease. In other words, detecting a disease only after the symptoms manifest may make the treatment difficult. By the time symptoms manifest, the concentration of the disease-causing pathogen (virus, bacteria, etc) is already very high in the body. Conventional methods such as urine or serum analysis cannot detect bacteria at low concentrations.

   Using biotechnology, techniques such as Polymerase Chain Reaction (PCR) and Enzyme-linked Immuno-sorbent Assay (ELISA) make the early detection of diseases possible.

PCR

In PCR, DNA from the sample is amplified and observed for the presence of pathogens. How does this work? A segment of DNA is collected from the patient and heated, causing the DNA to separate into two strands. This is called DNA denaturation. An enzyme known as 'Taq polymerase' (obtained from a bacteria called Thermus aquaticus) synthesises DNA from each strand. In other words, from a single DNA, two DNAs are produced. The DNA duplication continues, and in a few rounds, 1000s of DNA are produced. In other words, very low concentrations of pathogens are amplified and detected using PCR. It is generally used to test for HIV, gene mutations, or genetic disorders in suspected patients.

ELISA

Enzyme-linked Immuno-sorbent Assay (ELISA) test is used to diagnose a disease by identifying and measuring antibodies in blood. Antibodies are proteins produced in the body to fight against antigens. Antigen is a substance that is not recognised by the immune system. Each type of infection is characterised by a specific antigen. The immune system tries to fight against the infection by producing antibodies. In other words, the presence of antibodies indicates the presence of infection. In ELISA, the antigen (related to the condition for which the patient is being tested) is added to the blood sample. If antibodies are present in the blood against this particular antigen, they bind together, and the colour of the sample changes. The change in colour determines the presence of a particular pathogen. ELISA can be used to diagnose infections such as HIV, Lyme disease, rotavirus, syphilis, Zika virus, etc.

Genetically Engineered Insulin

Animal-sourced insulin (extracted from the pancreas of slaughtered cattle and pigs) was used to manage diabetes for many years before the advent of genetically-engineered insulin. Using genetic engineering, insulin is being produced from yeast and bacteria. A small piece of DNA called plasmid is extracted (this acts as the vector) from a bacteria (such as E. coli) or yeast cell and cut using the restriction enzymes. The plasmid is then modified by inserting the human insulin gene into the gap within the plasmid. The modified plasmid is then introduced into a host (new yeast or bacteria cell). The cell divides in the host and makes insulin. Large amounts of insulin can be manufactured by using this process.

Can Biotechnology Control Dengue and Chikungunya?

Trials are underway to develop transgenic *Aedes aegypti* variety in Jalna, Maharashtra, which will help in controlling dengue and chikungunya.

How Will This New Variety Reduce Disease?

Aedes aegypti vector mosquitoes, responsible for spreading dengue and chikungunya, among other diseases, are engineered through advanced biotechnology to be self-limiting—in other words, genetically modified so that their offspring will die.

Why Are Transgenic Mosquitoes Certain to Work?

The 'friendly Aedes' (modified *Aedes aegypti*) has already been trademarked by Oxitec (the research unit of Oxford University). These are transgenic male mosquitoes with a self-limiting gene inserted through advanced genetics. Banking upon the male's natural instinct to mate with a wild female, the OX513A strain is inherited by the offspring, causing the larvae to die before they mature to become adult mosquitoes.

White Biotechnology

The use of biotechnology in industry is regarded as white biotechnology. It helps to improve industrial processes and create new industrial products.

The uses of white biotechnology are mentioned below:

1. Biotechnology is used to develop microorganisms that can increase the rate of fermentation of organic matter in order to convert it into alcohol, acids, and biomass.
2. It is used to enhance oil recovery from its well. Genetically modified organisms by consuming dense hydrocarbons can reduce the surface tension of the oil to a greater extent and hence facilitate easy recovery of oil.
3. It is used to produce microorganisms, which can act as preservatives for perishable products.
4. It is used to produce biofuels, a renewable source of energy.

Use of Biological Processes for Extraction of Natural Resources

The following biological processes can be used for the extraction of natural resources:

1. **Biosorption:** It is a property of certain types of inactive, dead, microbial biomass to bind and concentrate heavy metals from even very dilute aqueous solutions.
2. **Biomining:** It is an approach for the extraction of desired minerals from ores with the help of living organisms.

   Biomining can be undertaken through microbes (microbial mining) or plants (phytomining).

3. **Bioleaching:** Microorganisms are used to leach out the minerals, rather than the traditional methods of extreme heat or toxic chemicals, which have a deleterious effect on the environment. Bioleaching is a sub-type of biomining. It is widely used as an extractive metallurgy technique which converts metal into soluble salts in aqueous media.
4. **Phytomining:** Phytomining is an approach in which mining is done with the help of plants. For instance, some plants absorb copper compounds through their roots. As a result, copper compounds remain concentrated in their roots. The plants can be burned to produce ash that contains copper.

Blue Biotechnology

Blue biotechnology deals with the aquatic environment (along with marine organisms) to generate new sources of energy, develop new drugs, extract useful resources, or develop new varieties of marine organisms.

Uses of blue biotechnology Biotechnology can be used to develop microorganisms to clean water bodies. For instance, oil spills can occur both over land as well as over water bodies. Oil spills over water bodies are more dangerous as the oil layer prevents the penetration of sunlight, leading to reduction of photosynthesis activity. Consequently, availability of oxygen in the water bodies is reduced, leading to the death of marine animals.

Oil zapper is a mixture of five types of bacteria which feed on hydrocarbon compounds present in the crude oil. The hazardous hydrocarbon waste generated by oil refineries is known as oil sludge.

Oil zapper converts hydrocarbons into CO_2 and H_2O. Oil Zapper consists of Oil Zapping bacteria, which are immobilised and packed into polythene bags. The shelf-life of oil zapper is three months. Oil zapper is used to clean oil spills.

Biotechnology can create transgenic aquatic organisms with desirable features. Transgenic aquatic organisms are those in which a foreign gene is added to the organisms to produce the desired qualities.

Uses of Biotechnology in Environment

Bioremediation

It refers to the cleaning of environment with the help of living organisms. Living organisms range from microorganisms to different species of plants. For example, bacteria help in the decomposition of organic waste, and certain plant species such as mustard helps in the absorption of poisonous elements such as selenium.

Bioremediation usually takes a longer time period. However, bioremediation effectively discriminates between pollutants and the required nutrients.

Strategies of bioremediation are mentioned below:

In situ bioremediation techniques It refers to the treatment of waste at its site. These techniques not only assist in the degradation of adsorbed fuel residuals but also assist in the degradation of volatile organic compounds. In situ bioremediation techniques include biosparging, bioventing, bioaugmentation, and bioculture.

1. **Biosparging:** It is an in situ remediation technology that uses indigenous microorganisms to biodegrade organic constituents in the saturated zone. In biosparging, air (or oxygen) and nutrients are injected at high pressure to increase the biological activity of the indigenous microorganisms and to enhance their decomposition activity.
2. **Bioventing:** It is an in situ remediation technology that uses microorganisms to biodegrade organic constituents adsorbed in soils in the unsaturated zone. Bioventing enhances the activity of indigenous bacteria and simulates the natural in situ biodegradation of hydrocarbons in the soil by inducing air or oxygen flow at low pressure into the unsaturated zone and, if necessary, by adding nutrients. In conventional bioventing systems, oxygen is delivered by an electric blower to subsurface wells.

Saturated zone requires injection of air and nutrients at high pressure, and unsaturated zone requires injection of air and nutrients at low pressure.

3. **Bioaugmentation:** In this technology, the microorganisms are imported to the contaminated site to carry out the degradation of organic waste. For instance, oil zapper (explained earlier).
4. **Bioculture:** It is a bacterial formulation to improve waste degradation in septic tanks and eliminate odours due to organic buildup. Bioculture refers to the use of blend of bacteria that collectively produce enzymes for the degradation of fats, oils, proteins, starch, and carbohydrates. Bioculture is specifically used for sewage treatment.

Ex-situ bioremediation techniques Ex-situ refers to the transfer of contaminated material for treatment to some other site. Ex-situ bioremediation techniques include land farming and biopile.

1. **Land farming:** In this technique, the contaminated soil is spread over a prepared bed. The soil is periodically tilled to stimulate the growth of microorganisms for the degradation of organic waste.
2. **Biopile:** It is a hybrid of land farming and composting. Excavated soils are spread over a prepared bed, formed into compost piles and enclosed for treatment.

   Moisture, heat, nutrients, oxygen, and pH are controlled to enhance biodegradation. An irrigation/ nutrient system is used to pass air and nutrients through the soil. Soil piles can be up to the height of 20 feet. They may be covered with plastic to control runoff, evaporation, and to promote solar heating.

   Treatment time is typically three to six months, after which the excavated material is either returned to its original location or disposed off.

   The treatment area is generally covered or contained with an impermeable lining to minimise the risk of contaminants leaching into the uncontaminated soil.

Bioremediation Techniques

1. **Phytoremediation:** It means using plants to remove contaminants from soil and water. Neem plant is used for phytoremediation as it absorbs poisonous elements and reduces the growth of harmful microorganisms.
2. **Phytoextraction:** It is a subprocess of phytoremediation in which plants remove dangerous elements or compounds from soil or water, mostly heavy metals, metals that have high density and are toxic to organisms even at relatively low concentrations.
3. **Mycoremediation:** It involves the use of fungus such as *mycelia* to decontaminate an area. *Mycorrhiza* is another type of fungus which is used for bioremediation. It also has other important uses in agriculture.

   '*Mycor*'–'*rhiza*' literally means 'fungus'–'root'. It exists in a mutually beneficial relationship with plant roots. These fungi develop on plant roots and extend far into the soil. Thereafter, these fungi act as extensions of root systems and are, in fact, more effective in nutrient and water absorption than the roots themselves. Mycorrhiza also protects plants against pathogens and toxic substances present in the soil. The fungus also facilitates restoration and helps in revegetation of disturbed mined lands.

What Is Synthetic Biology?

It is an emerging science through which new life forms can potentially be made in labs and existing life forms, such as bacteria and other microbes, are altered to produce specific proteins or chemically useful products.

Possible Benefits of Synthetic Biology

Synthetic biology in microbial systems holds promise for the production of drugs, vaccines, fuel components, and other chemicals. Microorganisms have also been constructed to act as sensors that can detect a toxin in vitro (outside a living organism) or in vivo (inside a living organism).

4 DRAWBACKS OF BIOTECHNOLOGY

1. Biotechnology can be used to develop Weapons of Mass Destruction (WMD). Biological weapons of mass destruction are cheap and easy to build. Moreover, these weapons have devastating effect only on living organisms and do not affect infrastructure.
2. Biotechnology can bring back certain extinct forms of life, which may lead to some unpredictable and harmful consequences. For instance, the smallpox virus can be regenerated and left in the environment to infect people.
3. Biotechnology may have a negative effect on biodiversity. At present, few plant and animal species are the focus of research, leading to ignorance of other species. The focus on few species may lead to their growth and can have a negative effect (even extinction) on remaining species.

4. Biotechnology is used to develop plant varieties with terminator genes. A terminator gene in a genetically modified crop plant stops the plant from releasing fertile seed. Hence, the farmer is again required to purchase the seeds in the next cropping season. The practice of incorporating terminator gene trait in some seed varieties is adopted by multinational companies (MNCs) to enhance their sale of seeds. This terminator trait may cross-pollinate with local varieties and may affect the continuity of agriculture.

5 CLONING

It is a process of asexual reproduction in which the offspring or the progeny is an exact replica of the single parent donor who has contributed the genetic material. Cloning is possible because each cell is equipped with genetic information of an organism, which has the ability to develop into full organism.

In contrast, in sexual reproduction, the progeny inherits genetic material in an equal amount from both the parents.

Cloning in animals is used to produce duplicates of animals. The first successfully cloned animal was a sheep called Dolly in 1997 at Roslin Institute of Technology, Scotland. Since then, a large number of animals have been cloned.

The following are India's achievements in animal cloning:

1. **Samrupa:** In 2009, the world's first cloned buffalo calf, named Samrupa, was developed by National Dairy Research Institute (NDRI) in Karnal, Haryana. But unlike Dolly, the first mammal cloned 13 years ago, who lived for seven years, Samrupa succumbed to a lung infection just five days after it was born.
2. **Garima:** It was the world's second cloned buffalo at NDRI in Karnal, Haryana. It was developed in 2009 and survived for more than two years. It died because of heart failure in 2011.
3. **Cirb Gaurav:** In 2016, the scientists at the Central Institute for Research on Buffaloes (CIRB) in Hisar, Haryana, cloned a buffalo offspring named 'Cirb Gaurav'.

Human Cloning

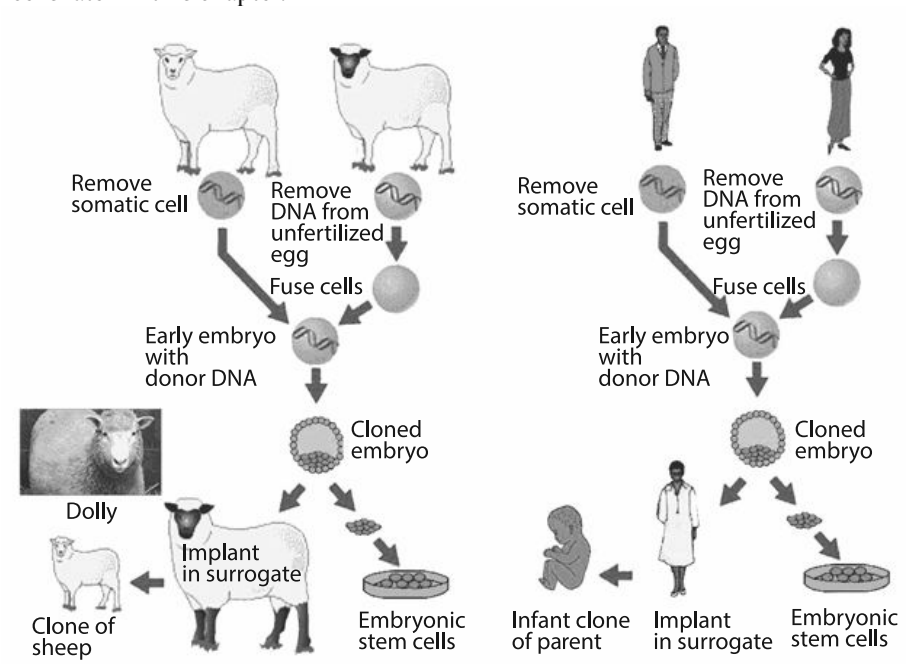
The process of creating a genetically identical copy of a human being, human cell, or human tissue is called human cloning.

Process of Cloning

Human cloning is performed by somatic cells (any cells in the body other than sperm and egg, the two types of reproductive cells) by a nucleus transfer to an enucleated egg (an egg cell whose nucleus has been removed). The egg so obtained is then stimulated by electric shock and chemicals to initiate division. Within a week, this single cell becomes a ball of mass, having around 150 unspecialised cells. This stage of development is called 'blastocyst'. The blastocyst is inserted into the uterus of a surrogate mother to complete the process of embryonic development.

There are two types of cloning: reproductive and therapeutic. The difference between the two is listed below:

1. In reproductive cloning, the newly created embryo is placed back into the uterus, where it can develop into an individual. Reproductive cloning is the production of a genetic duplicate of an existing organism. A human clone would be a genetic copy of an existing person.
2. Therapeutic cloning involves the replication of human embryos in order to harvest stem cells for medical uses. In therapeutic cloning, an embryo is created in a similar manner, but the resulting 'cloned' cells are stored in the lab; they are not implanted into a female's uterus. We will learn about the stem cells later in this chapter.



Concerns over Reproductive Human Cloning

Reproductive human cloning is opposed on various ethical grounds.

1. It may undermine society's respect for human life. It may happen that clones are treated as secondary race or even as slaves.
2. It may affect social institutions such as marriage and family. A single parent may go for reproductive cloning.

   Children born out of reproductive cloning may be treated secondary in the family. A cloned son of a man would be his identical twin. This would create a set of very complicated family relations. Thus, the institution of family may be affected.
3. Reproductive Cloning (RC) may create a global security concern. Nations or even terrorist organizations may create cloned armies.
4. The RC may emphasize infusing desirable traits in clones. This may promote the concept of 'designer babies', babies who are genetically engineered to exhibit desirable characteristics.

5. Experiments and research on cloning require working on embryos. This is opposed because, according to some religious organizations, life begins at conception.

How Is RC Different from Surrogacy?

1. **Process:** In case of cloning, a somatic cell is taken from a donor to create an embryo. This child is born of a single parent and carries his/her DNA only.

   In an In Vitro Fertilization (IVF) or test tube baby, an egg fertilized by a sperm (creating a zygote) is transferred into the uterus. It creates a progeny similar to normal conception. The child carries the DNA of both his/her parents.
2. **Uniqueness of progeny:** Biologically, a child from IVF is a unique human (unless he/she has an identical twin), while a cloned child is genetically identical to his/her parent.
3. **Lifespan:** Shortened lifespan has been reported in many cases of animal cloning. The progeny born out of IVF leads a normal life.
4. **Ethical issues:** The ethical issues with IVF are not questioned as much as RC. Both IVF and RC help infertile couples and same-sex couples with their parenting rights.

   This, in turn, has led to the commercialization of IVF and creation of 'contract mothers'. Many conservatives also believe that it is a commodification of children, where the social perception of motherhood and fatherhood changes and turns the baby into a commodity.

6 STEM CELLS

Stem cells are the raw materials for other body cells. They are considered raw materials because all other cells with specialised functions are generated from these cells.

In other words, stem cells are unspecialised cells that have not yet developed into mature, specialised cells. These cells have the ability to develop into different, specialised body cells.

Stem cells have the following two important properties:

1. **Ability of self-renewal:** The ability of stem cells to go through numerous cycles of cell division while maintaining the undifferentiated state is called self-renewal.

   Under the right conditions in the body or a laboratory, stem cells divide to form more cells called daughter cells.

   These daughter cells either become new stem cells (self-renewal) or become specialised cells (differentiation) with a more specific function. No other cell in the body has the natural ability to generate new cell types.
2. **Ability to specialise:** The stem cells have the capacity to differentiate into specialised cell types. They have the ability to specialise in various body cells types such as blood cells, brain cells, heart muscle, or bone.

Sources of Stem Cells

Stem cells are obtained from the following sources:

1. **Embryonic stem cells:** These stem cells come from embryos three to five days after conception. At this stage, an embryo is called a blastocyst and has around 150 cells.

These stem cells are pluripotent stem cells, meaning they can divide into more stem cells or become any type of cell in the body. Thus, these stem cells can be used to regenerate or repair diseased tissues and organs.

2. **Adult stem cells:** These stem cells are found in small numbers in most adult tissues, such as bone marrow or fat. Compared to embryonic stem cells, adult stem cells have a limited ability to specialise in various cells of the body.

   For instance, bone marrow stem cells may create bone or heart muscle cells, but not nerve cells. The research involving adult stem cells is undergoing clinical trials to test its usefulness and safety in people. For example, adult stem cells are currently being tested in people with neurological or heart disease.

   Scientists have also successfully transformed regular adult cells into stem cells using genetic reprogramming. By altering the genes in the adult cells, researchers can reprogram the cells to act like embryonic stem cells. These stem cells are called induced pluripotent stem cells.

   However, researchers are yet to know if these reprogrammed cells will cause adverse effects in humans.

3. **Perinatal stem cells:** Perinatal means relating to time, usually a number of weeks, immediately before and after birth. Researchers have discovered stem cells in amniotic fluid in addition to umbilical cord blood stem cells. These stem cells also have the ability to change into specialised cells. Clinical trials are undertaken to understand the potential of amniotic fluid stem cells.

Totipotent, Pluripotent and Multipotent Stem Cells

We have learned that stem cells have the ability to develop into specialised body cells. On the basis of their ability to develop into specialised cells, stem cells can be divided into three types- Totipotent cells, Pluripotent cells, and Multipotent cells.

Totipotent cells: Totipotent is made up of two words- 'Toti' means 'entire or whole' and 'potent' word is used to reflect 'capability or dominance' of something. Thus, Totipotent stem cells are the type of stem cells that can be specialised into an entire range of cell types in the body, including embryonic and placental cells. Thus, these cells are capable of developing into a complete organism.

Therefore, these cells have the maximum ability to specialise into any cell type. Embryonic cells within the first two cell divisions after fertilization are the only cells that are totipotent.

Pluripotent cells: The word 'Pluri' means 'many'. Pluripotent cells are the stem cells that can be specialised into all the cell types that make up the body. However, they cannot be specialised into embryonic and placental cells. Thus, the ability of Pluripotent cells to specialise is less than the Totipotent cells' as the Pluripotent cells cannot specialise into embryonic and placental cells. Pluripotent stem cells can be are sourced from embryonic stem cells.

Multipotent cells: The word 'Multi' means 'more than one or a few'. Multipotent cells can be developed into more than one cell type, but their ability to specialise is limited to pluripotent cells. Multipotent stem cells can be obtained from adult stem cells and umbilical cord blood stem cells.

Totipotent, Pluripotent, and Multipotent stem cells can also be understood through one more approach. Tutipotent stem cells can be obtained from embryos within the first two cell divisions after fertilization. As embryo develops, Pluripotent cells can be obtained from the embryo. Once an embryo develops into specialised cells and takes birth, then only multipotent stem cells can be obtained.

Uses of Stem Cells

Stem cells have the following applications:

1. **Increased understanding of how diseases occur:** By watching stem cells mature into cells in bones, heart muscles, nerves, and other organs and tissues, researchers and doctors may better understand how diseases and conditions develop.
2. **Generate healthy cells to replace diseased cells (regenerative medicine):** Stem cells can be guided to become specific cells that can be used to regenerate and repair diseased or damaged tissues in people.

   People who might benefit from stem cell therapies include those with spinal cord injuries, Type 1 diabetes, Parkinson's disease, Alzheimer's disease, heart disease, burns, cancer, and osteoarthritis.
3. **Test new drugs for safety and effectiveness:** Before using new drugs in people, some types of stem cells are useful to test the safety and quality of investigational drugs.

   For testing new drugs, the cells are programmed to acquire properties of the type of cells to be tested. For instance, nerve cells could be generated to test a new drug for a nerve disease. Tests could show whether the new drug had any effect on the cells and whether the cells were harmed.

Ethical Issues in the Use of Stem Cells

Embryonic stem cells are obtained from early-stage embryos—a group of cells that forms when a woman's egg is fertilised with a man's sperm. Thus, the use of embryos to obtain stem cells is opposed by some religious bodies which believe that life begins immediately after fertilization.

Problems with the Use of Adult Stem Cells

Adult stem cells have limited ability to specialise, which limits how adult stem cells can be used to treat diseases.

Adult stem cells are also more likely to contain abnormalities such as toxins or errors acquired by the cells during replication.

Organoids

Organoids are tiny, self-organized, 3D tissue cultures, grown from stem cells in a controlled environment. In other words, organoids are tiny, functional versions of a fully grown organ. Their size ranges from 200 microns to a few millimeters. Organoids can be derived from all three types of stem cells. Organoids resembling the brain, lungs, intestine, liver, kidney, heart, eyes, inner ear, pancreas, salivary glands, and stomach, among others, can be developed.

Applications of Organoids

Organoids find numerous applications in the fields of medical research, diagnosis, pathology (study of diseases), and treatment of diseases. These applications include:

Medical Research: Organoids can contribute significantly to embryology by demonstrating how specific organs are developed from the embryo. Earlier, scientists used to rely on the studies on mice and other animals and extrapolate these studies to understand how human embryonic development takes place.

Research on diseases: Organoids can be used to understand how a disease affects a particular organ system. For instance, to study how Microcephaly (a neurological condition in which an infant's head is significantly smaller) affects the patients, cerebral organoids can be cultured from a patient and studied.

Pharmaceuticals: Organoids can be used in testing of drugs and clinical trials. Organoids successfully replaced host animals like mice and primates in certain cases for drug testing. They can also improve the efficiency of the testing processes in certain cases where the diseased animals may not show a response similar to humans.

For instance, in the case of COVID-19, mice infected with SARS-COV-2 were not exhibiting the immune response seen in humans. As a result, it becomes difficult to draw reliable conclusions by using mice for drug testing. To overcome this issue, mini lungs (organoids) are developed and exposed to SARS-COV-2. The organoids showed an aggressive immune response. During the testing, virus infected blood vessel organoids was observed. This helped explain how the virus reaches other organs through bloodstream. Subsequently, COVID drug trials on mini lungs were used to isolate the compounds which reduced viral levels in mini lungs.

Organoids can also help to improve the efficacy and safety of certain drugs and reduce any allergic reactions. They can also be used in developing patient-specific drug interventions that will significantly reduce anaphylactic responses (severe potentially life-threatening allergic reactions) to drug administration.

Treatment of genetic diseases: Further, Organoids can also be used in the treatment of genetic diseases. For instance, they can be used in tissue transformation and transplantation to mitigate the effect of genetic anomalies. Researchers have shown that when intestinal cells are transformed into insulin producing beta cells and transplanted into a diabetic mouse, these cells regulate the blood sugar levels of the mouse.

Limitations to the Use of Organoids

1. Despite the advantages, there are some ethical and legal concerns around the use of organoids. For instance, scientists are worried about the unethical use of organ culture to produce organs of commercial interest which may not fulfill the necessary criteria. This can potentially boost illegal organ trade and even the trade of organs with sub-optimal functioning.
2. Organoids can exhibit only the basic functions of an organ, as they are still at the initial stages of organ development. For example, cerebral organoids lack the manifestation of consciousness and, therefore may be useless in the treatment of certain psychological disorders. Thus, there is a significant limitation on the use of organoids for medical treatments.
3. The immune responses of the organoids and the actual organs may vary, as organoids are grown in controlled environments. This means their acquired immunity levels are lower than those exhibited by the actual human organs. These differences should be taken into account while conducting drug trials.

7 DNA FINGERPRINTING

DNA fingerprinting refers to identifying a complete (or partial) set of genetic information of a particular individual. It is essentially a DNA-based identification system that relies on genetic differences among individuals or organisms. A sample of blood, saliva, semen, vaginal lubrication, or other appropriate fluid or tissue from personal items can be used for DNA fingerprinting.

Like fingerprints, every human has unique DNA; unlike fingerprints which can be surgically altered, one cannot change the DNA. The DNA fingerprinting is also known as DNA analysis or DNA profiling.

What Is DNA?

Deoxyribonucleic acid (DNA) is the genetic material typically found in all living cells of humans as well as animals and plants. It invariably contains hereditary data passed on from parent to children, which is unique to each person (except in the case of identical twins). This makes DNA profiling a reliable and unique personal identification tool.

Applications of DNA Fingerprinting

1. **Identification of criminals:** DNA analysis of hair, bodily fluids, skin, etc., obtained from a crime scene is used to compare with the DNA analysis of suspects to identify the actual criminals.
2. **Claim over dead body:** DNA fingerprinting is used to identify the unrecognizable dead body.
3. **Paternity:** Paternity can be established with certainty with DNA analysis.
4. **Effective drugs:** Drugs can be developed which are more effective for a particular genetic disposition.
5. **Treatment of genetic vulnerability:** Genetic vulnerabilities can be identified beforehand and prevented. For instance, if a person has a genetic tendency for hypertension, then preventive steps can be taken to prevent the occurrence of hypertension.
6. **Wildlife management:** The more the genetic makeup of plant and animal populations is understood, the better conservation and management plans can be formulated.

Concerns Over DNA Fingerprinting

1. The information about gene pool can lead to a preference for designer babies and ignore the genes of undesirable characteristics, thus reducing genetic diversity.
2. Genetic privacy of individuals will be violated. It can have multiple repercussions. For instance, a person with a particular genetic vulnerability may be looked down upon socially.
3. Genetic information can be misused for commercial purposes. For instance, medical institutions will start offering medical packages based on DNA analysis.
4. Genetic information may be used to create weapons of mass destructions, leading to ethnic cleansing of a particular community.

8 GENE THERAPY

Gene therapy is a medical technique that manipulates genes to treat or prevent a disease. Gene therapy research is focused on the following approaches:

- Replacing a gene responsible for disease with a healthy gene.
- Inactivating or 'knocking out' a gene that is functioning improperly.
- Introducing a new gene into the body to help fight a disease.

In the future, this technique may allow doctors to treat a disorder by manipulating a gene into a patient's cells instead of using drugs or surgery. Gene therapy is a treatment option for a number of diseases (including inherited disorders, some types of cancer, and certain viral infections).

Use of Vector to Introduce a Gene

Usually, a gene that is inserted directly into a cell does not function on its own. Instead, a carrier called vector is genetically engineered to deliver the gene. Certain viruses such as retrovirus are often used as vectors because they can deliver the new gene by infecting the cell. The viruses are modified not to cause disease when inserted into people.

The vector can be injected or given intravenously (by IV), directly into a specific tissue in the body, where it is taken up by individual cells. Alternately, a sample of the patient's cells can be removed and exposed to the vector in a laboratory setting. The cells containing the vector are then returned to the patient. If the treatment is successful, the new gene delivered by the vector will make a functioning protein.

Concerns Over Gene Therapy

1. **Short-lived nature of treatment:** Before gene therapy can become a permanent cure for a condition, the therapeutic DNA introduced into the target cells must remain functional and the cells containing the therapeutic DNA must be stable. Problems with integrating therapeutic DNA into the genome and the rapidly dividing nature of many cells prevent it from achieving long-term benefits. Patients undergoing gene therapy often require multiple treatments.
2. **Immune response:** Depending upon the number of times a foreign object is introduced into our body, the immune system is stimulated to attack the invader. As a result, the gene therapy might activate the response of our immune system. Even our immune system reduces the effectiveness of gene therapy.
3. **Multi-gene disorders:** Some commonly occurring disorders such as heart disease, high blood pressure, Alzheimer's disease, arthritis, and diabetes are affected by variations in multiple genes, which complicate the use of gene therapy.

   Presently, the technique remains risky. It is not yet proven to be safe and effective. Gene therapy is currently being tested only for the treatment of diseases that have no other cures.

9 DNA OR THIRD-GENERATION VACCINES

DNA vaccines are also called third-generation vaccines. These vaccines are made up of a small, circular piece of bacterial DNA (called plasmid) or virus that has been genetically engineered to produce one or two specific proteins (antigens) from a pathogen.

In the DNA vaccine, a piece of bacterial DNA (plasmid) carrying antigens is directly given to us, and our body absorbs the DNA into our genetic system. Our body then replicates the production of plasmid-carrying antigen. This release of antigen by our own DNA activates our immune system. Like any vaccine, the immune system will then recognize the bacteria or virus in the future—hopefully preventing illness.

What Are the Advantages of DNA Vaccines?

1. **Require short time span for development:** Quick changes can easily be brought in gene-based vaccine than bacteria- or virus-based vaccine. Such changes are important to deal with strains of bacteria or viruses that are constantly mutating.
2. **DNA vaccines are easy to transport and store:** DNA is a very stable molecule and does not need to be stored at low temperatures, making transportation and storage cheaper and easier than conventional vaccines.
3. **Less risk to those who are making the vaccine:** Conventional vaccines require raising up the infectious bacteria or virus. Thus, there is a risk (even though small) to those who make the vaccines, whereas making DNA vaccines is less risky.

What Are the Disadvantages of DNA Vaccines?

So far, no DNA vaccine has been licensed for the use in humans. Although some DNA vaccines are now in clinical trials, none are licensed for use.

First-generation Vaccines

These vaccines consist of infectious organisms, either in mild or dead form. The first-generation vaccines are still widely used today.

Live and mild/attenuated forms of infectious organisms produce both humoral (antibody) and cellular immune responses. For example, an oral polio virus vaccine uses polio virus in mild form. When we take the vaccine, our body reacts as if it is affected by an actual virus. Consequently, our immune system gets activated and T-killer cells attack the polio virus. Thereafter, when there is any actual attack of polio virus, then our immune system is already developed to handle such an attack.

The only problem with these vaccines is that the actual pathogen in these vaccines may take a dangerous form.

Dead pathogen vaccines do generate an antibody response but they do not generate cellular responses (no T-killer response). Depending on the disease, antibody production may or may not be enough to ward off infection. The advantage of using killed pathogen vaccine is that there is no chance of infection from the vaccine.

T-killer cells are T-lymphocytes (a type of white blood cell); these cells kill other cells that are infected (particularly with viruses) or cells that are damaged in other ways.

Second-generation Vaccines

The second-generation vaccines were created in order to minimise the risks of pathogen revert to a dangerous form.

The way these vaccines work is that they do not contain the whole organism, but rather contain only subunits. Subunits may consist of the toxins that the pathogen uses for infecting the body. A great example of second-generation vaccine is DTP vaccine. The second-generation vaccines can generate antibody response but not T-killer response.

10 CRISPR-CAS9

CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats. This is the name given to unique DNA structures found in bacteria and other microorganisms, which constitute a key part of their 'immune system'. If a virus enters bacteria, the CRISPR immune system fights back by destroying the genome of the virus. It cuts the invading virus's DNA, and as a result, the genetic material which is necessary for the replication of the virus is destroyed. Hence the CRISPR immune system protects bacteria from the viral infection.

Moreover, the bacteria also store some of the invading virus's DNA. When there is an attack by any virus in the future, the bacteria produce an enzyme called Cas9 (CRISPR- associated) endonuclease or Cas9 enzyme. The Cas9 matches the fingerprints stored earlier with that of the new invading virus. If the fingerprints match, the new virus is the same as the earlier virus that invaded the bacteria. The Cas9 then acts as a molecular scissors and snips the invading virus's DNA. The location at which Cas9 needs to cut the DNA is specified by the RNA sequence of CRISPR. CRISPR-Cas9 finds applications in gene editing where it is used as a gene-editing tool.

Gene-editing tool: The CRISPR-Cas9 gene editing tool comprises two components: a mechanism to identify a specific target and a molecular scissor. A short RNA sequence binds to a specific target of the DNA and the Cas9 enzyme cuts the DNA at the location where RNA sequence is bound. The natural DNA repair mechanism kicks in after the DNA is cut. This mechanism is utilised to make the required changes to the DNA, to add or remove genetic material. For instance, during this auto-repair process, scientists may intervene to supply a desired gene sequence that binds with broken DNA. In simple terms, to draw an analogy, CRISPR-Cas9 works like the 'Find and Replace' function in a word processing program such as Microsoft word.

Applications of CRISPR-Cas9

CRISPR-Cas9 can be used in a wide range of applications such as industry, medicine, and research. For instance, industrial processes that use bacteria (e.g., fermentation based industries such as dairy, distilleries) can use the CRISPR system to make the bacterial cultures resistant to any particular viral attack, and hence increase productivity.

CRISPR technology is also used in medical research to understand how a particular gene affects an organism. Scientists can change the gene of interest and study how it affects the organisms. Further, this tool can be used to silence a particular gene—delete, correct, or insert a new gene.

In medicine, the tool may be used in the treatment of genetic diseases. For instance, in persons with sickle cell anemia, a mutation causes the red blood cells to be sickle shaped. This hinders their capability to carry out oxygen throughout the body. In such cases, by changing a single gene, the mutation can be reversed. Thus, the disease can be cured using gene editing. Along with genetic diseases, infectious diseases can also be treated using gene-editing technologies. For instance, specific antibiotics which selectively target only disease-causing bacteria can be developed to treat infectious diseases.

The He Jiankui affair

In 2018, a Chinese scientist He Jiankui claimed that he created the world's first genetically edited babies. This raised international furore and a series of questions on the ethical and legal issues surrounding the use of gene editing and use of tools such as CRISPR-Cas9.

What Did the Scientist Claim?

The scientist claimed to have carried out assisted reproduction in a couple, where one of them had HIV. During the in-vitro fertilisation, he used the CRISPR-Cas9 tool to disable a gene CCR5 in the embryo. CCR5 encodes a protein, and it allows HIV to enter and infect the host cells. By disabling this, the doctor claimed to have made HIV-resistant babies. He also claimed to have implanted a gene-edited embryo in another woman.

Why Is it Illegal and Unethical?

There is an international consensus that gene editing should not be used on Human embryos until sufficient international protocols are developed to prevent its misuse. Moreover, research still needs to be carried out on the long-term health impacts if such gene modifications are done in babies.

In this case, though it is believed that HIV enters and infects the host through gene CCR5, there were no clinical trials carried out anywhere in the world to test the same. Hence, the efficacy of such procedures and the side effects are not known. Further, the CCR5 gene plays an important role in protecting against viral infections such as west nile viral infection. Without this gene, babies are more susceptible to such virus infections. Moreover, the X4 form of HIV uses a different protein to enter the cells (not CCR5). Hence, babies may not be resistant to HIV from this source of infection.

Scientists and policymakers argue that if gene editing on human embryos is allowed, it may lead to several unintended consequences. For instance, people may choose to edit embryos for very specific qualities such as desirable physical attributes, intelligence, and so on. As genes pass on from one generation to another, this may inadvertently alter the genome of future generations. Hence, guidelines need to be established to ensure that the genetic engineering tools are used in very specific and rare cases such as treating diseases with no alternative treatments.

What Was the Outcome in He Jiankui's Case?

The Chinese court sentenced the doctor to three years in prison for violating medical regulations and ethics. The court claimed that the doctor flouted the medical regulations and ethics in the pursuit of "fame and profit".

11 FOOD FORTIFICATION

Food fortification refers to the process of adding certain important vitamins and minerals to staple foods to improve their nutritional content.

The common staple foods that are fortified include wheat, rice, milk, oil, and salt. The commonly added vitamins and minerals are iron, zinc, iodine, vitamin A and vitamin D, to name a few. These nutrients may not be originally present in these food items or may have been lost during their processing. Adding these nutrients improves the nutritional content of food and helps address the malnutrition in the population.

The following are the benefits of food fortification:

1. Since nutrients added to staple foods are consumed by a large section of the population, food fortification helps in addressing nutrition deficiencies effectively at overall nation level.
2. The small quantities of nutrients are added, which do not pose any health risks on account of their consumption. In other words, fortified foods are safe to be consumed.
3. It is a cost-effective method and does not need any major changes in the existing food habits of the people. This makes it a socio-culturally acceptable method to deliver the required nutrients.
4. The food characteristics such as taste, texture, or aroma are not altered.

Some of the commonly used fortified foods and their benefits are given below:

Type of Fortified Food	Commonly added nutrients	Benefits
Salt	Iodine	Iodine deficiency occurs because crops are grown on iodine-deficient soils. Fortification of salt with iodine addresses various iodine deficiency related disorders effectively as salt is a food item that is consumed daily and almost universally. Iodine deficiency disorders include goitre, brain damage, hypothyroidism, intellectual disability, etc.
Double Fortified Salt	Iron and Iodine	Double Fortified Salt (DFS) formulations can provide 100% of dietary iodine requirements and 30 to 60% of dietary iron requirements.
Milk	Vitamin A and D	Milk is a natural source of vitamins A and D. However, these vitamins are lost when the milk is processed. Hence the lost vitamins are compensated by adding these vitamins back to milk.
Edible oil	Vitamin A and D	Vitamins A and D are added to edible oils to address the micronutrient deficiencies. Fortified oil can provide around 25% to 30% of the daily dietary requirements of vitamins A and D.

Rice	Iron, Folic acid (man-made version of Vitamin B9) and Vitamin B12	Fortification of rice can be done by adding the vitamins and minerals in the post-harvest phase. Since rice is an important staple food of around 65% of the Indian population, the essential nutrients can easily reach the large population. Further, rice is also supplied by the Government's public distribution system and is easily accessible across the country. This makes it a preferred food to deliver the essential micronutrients.
Wheat Flour	Iron, Folic acid, Vitamin B12, Zinc, Vitamin A, Other B-Complex Vitamins such as Thiamine (B1), Riboflavin (B2), Niacin (B3) and Pyridoxine (B6)	Wheat is also an important staple food of Indians, especially in the wheat-growing regions of north, west and central India. Similar to rice, it is an effective way to deliver nutrients and prevent diseases such as anemia.

12 GENETICALLY MODIFIED ORGANISMS

Genetically Modified Organisms (GMOs) are organisms whose genetic materials have been altered using genetic engineering techniques to provide the organisms with certain special characteristics. GMOs can include plants, animals, and even microorganisms.

We have learned that genetic modification can lead to various benefits. GMO research in animals is at the nascent stage. However, it has attained some success in plants. Many genetically modified plant varieties have been developed.

Some of the popular genetically modified crops are mentioned below:

1. **Golden rice:** We have already discussed Golden Rice in this chapter. At present, research on Golden Rice is taking place. It is not yet commercially cultivated.
2. **Bt cotton:** We have already discussed that Bt cotton is a transgenic crop in which 'Cry1 AC' gene of Bacillus thuringiensis is introduced to make the pest-resistant crop. After the introduction of this gene, the cotton crop starts producing its own pesticide. The Bt trait is believed to save the cotton plant from the pest popularly known as bollworm.
3. **Bt brinjal and Bt mustard:** Bt brinjal and Bt mustard have been developed on the lines of Bt cotton. These crops are also transgenic in nature in which 'Cry1 AC' gene of Bacillus thuringiensis is introduced to make the pest-resistant crop.

Position of Genetically Modified Crops in India

At present, commercial cultivation of edible, genetically modified (GM) crops such as Bt brinjal and Bt mustard is not allowed because of the following reasons:

1. Presently, research is not enough to understand the impact of Bt food crops on human health. The regular consumption of such varieties may have long-term repercussions on health.
2. Bt trait food crop may cross-pollinate with local wild weeds to make them superweeds, which would then require a large amount of pesticides for their elimination.
3. Moreover, there is a strong opposition from some groups for the cultivation of GM crops. Farmer groups oppose the cultivation of GM crops because promotion of sale of GM crops would hamper the sale of non-GM crops. NGOs such as Greenpeace stringently oppose the cultivation of GM crops.

On the other hand, commercial cultivation of non-edible Bt crops is allowed. For instance, Bt cotton crop is cultivated at many places in India.

GM Mustard (DMH-11)

Mustard is a self-pollinating crop. Hence, it is difficult to develop a hybrid of mustard. In other words, it is difficult to cross pollinate a mustard crop. In 2016, researchers of the Delhi University have genetically modified an Indian mustard (Varuna) and an East-European mustard to cross-pollinate them. After cross-pollinating these genetically modified mustard varieties, the new variety of mustard developed was named Dhara mustard hybrid (DMH)-11.

Researchers have sought permission for the following:

1. To commercially release DMH-11 and
2. To use the two GM parental lines, Indian and East-European, for developing new hybrids.

Benefits claimed from DMH-11include:

1. DMH-11 yields about 30% more than the traditional reference mustard variety.
2. It will help in boosting edible mustard oil production; thus, reducing the huge import bills for edible oil.
3. GM mustard is resistant to herbicides.

Views of Government on GM Mustard

Our government has given the required permission to the researchers to develop GM mustard. The Genetic Engineering Appraisal Committee (GEAC) is the government agency responsible for granting permission for research on genetically engineered organisms and products.

Views of Supreme Court on GM Mustard

The Supreme Court has stayed permission to develop GM mustard. It holds that the approval for GM mustard has been given without consulting people. Moreover, it holds that denying citizens a voice in this matter is all the more serious, considering that no labeling regime is in place in India. Without proper labeling, citizens will not know whether they consume food made from GM mustard.

GM Rubber Plant

The world's first genetically modified rubber plant has been developed at the Kerala-based Rubber Research Institute of India (RRII). The GM rubber plant was planted for the first time on the outskirts of Guwahati, Assam, in the year 2021. Natural rubber is a native of warm, humid Amazon forests. Consequently, GM rubber plant has been developed to suit the colder conditions in the Northeast, one of the largest producers of rubber in India.

Genetic Modification

The cold conditions during the winter months lead to drying of the soil and thus, hamper the growth of rubber plants. The GM rubber has additional copies of the gene MnSOD or manganese-containing superoxide dismutase, inserted in the plant. The additional copies of gene MnSOD are expected to tide over the severe cold conditions during winter. The MnSOD gene has the ability to protect plants from the adverse effects of severe environmental stresses such as cold and drought. GM rubber plants overexpress the MnSOD gene and thus, offer protection to the cells. The plant is thus expected to establish well and grow fast even in harsh conditions.

Genetic Engineering Appraisal Committee

The Genetic Engineering Appraisal Committee (GEAC) was formed under the Environment Protection Act, 1986, and functions under the Ministry of Environment, Forest and Climate Change (MoEFCC). It gives approval for the cultivation of GM crops.

The functioning of GEAC has the following loopholes:

1. The GEAC is not an autonomous body as it functions under MoEFCC. Thus, while approving for genetically modified crops, the GEAC may come under pressure from MoEFCC.
2. Moreover, the GEAC does not possess independent research capabilities. It gives approval based on the research report furnished by the MNCs that seek approval for the cultivation of genetically modified crops.

There is a need to setup Biotechnology Regulatory Authority of India (BRAI), which would be an autonomous body. Moreover, the BRAI shall possess independent research facilities to verify the claim made by the MNCs for a particular GM crop. These research facilities shall also be able to assess long-term impact of GM crop on health and environment.

13 INTERDISCIPLINARY DEPENDENCY OF BIOTECHNOLOGY

Biotechnology is dependent on many disciplines and techniques for accumulation of data, its organization and analysis. Some of these disciplines are mentioned below:

Biological Engineering

Biological Engineering or Bioengineering is an interdisciplinary area focusing on the application of engineering principles to analyse biological systems and solve problems relating to biological systems with human-designed machines, structures, processes, and instrumentation.

In many cases, currently available knowledge is inadequate to support the engineering design of biological processes. Hence, fundamental knowledge of biology and its potential applications remain a focus of biological engineering.

Examples of bioengineering include:

- Artificial hips, knees, and other joints.
- Ultrasound, MRI, and other medical imaging techniques.
- Using engineered organisms for chemical and pharmaceutical manufacturing.

Biomimetics

Biomimetics, also known as biomimicry, is the usage and implementation of concepts and principles from nature to create new materials, devices, and systems.

This adaptation of methods and systems found in nature into man-made products is desirable because living organisms have evolved into well-adapted structures and materials over geological time through natural selection. Moreover, human beings have looked at nature for answers to problems throughout their existence. Nature has solutions to many problems such as self-healing abilities, environmental exposure tolerance and resistance, harnessing solar energy, etc.

A simple example of biomimetics is the inspiration to develop Velcro tape from the hooks on Burdock burrs.

Velcro tape

Bionics

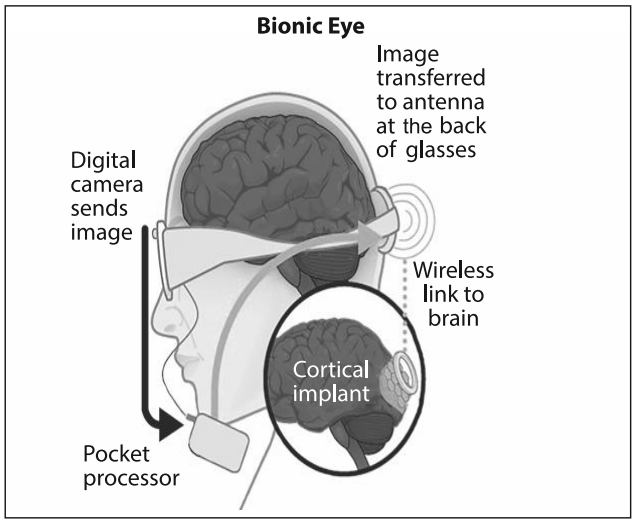
Bionics can mean different things to different people. It started as a term for the application of principles of biology to engineering. Now it is used to describe a method to engineer organs that can replace

diseased or non-functional human organs. In the future, it could also be a way to design machines that can mimic biological behaviour. Thus, the term bionics is related to biomimetics. Bionics is distinct from bioengineering (or biotechnology), which is based on the use of actual living organisms.

Under the traditional method, well-fitting limbs such as wooden leg or a glass eye were made for persons who had lost legs or eyes. Bionic technology does not stop at making well-fitting prostheses. The term 'bio' in the word 'bionic' refers to artificial eyes or limbs such as legs or arms, which can carry out functions like normal limbs.

Example of bionic eye Bionic eye is an artificial device that has been developed to restore vision. The device includes, among other things, a small video camera, a transmitter mounted on a pair of glasses, and an implant in the brain, which works as a wireless link between the transmitter and the brain.

This new surgically implanted assistive device provides an option for patients who have lost their sight, for which there are no approved treatments.



Bioinformatics

The recent flood of data from biology and the need for its organization have given rise to a new field, namely, bioinformatics, which combines the elements of Biology and Computer Science. Think about the data generated by more than three billion nitrogen pairs in a human body which form the gene sequences of an individual!

Bioinformatics begins with conceptualizing biological processes and systems and then applying 'informatics' techniques (derived from disciplines such as Applied Mathematics, Computer Science, and Statistics) to understand and organise the information associated with these processes and systems on a large scale.

14 DEPARTMENT OF BIOTECHNOLOGY

The Department of Biotechnology was set up under the Ministry of Science and Technology in 1986. It replaced the National Biotechnology Board, which was earlier set up in 1982. The department is involved in the planning, promotion, and coordination of research and development in the area of biotechnology. The responsibilities of the department are as follows:

- Creation of policy frameworks
- Promote innovation and excellence
- Support research activities in the applications of biotechnology in fields such as:
  - agriculture and nutritional security
  - healthcare and medical biotechnology
  - environmental safety
  - new generation biofuels
  - animal and aquatic sciences
- Ensure that the benefits of biotechnology reach the community at large.

Project "Genome India"

The Genome India Project was initiated in January 2020 by the Department of Biotechnology. The project aims to build a reference genome by collecting 10,000 genetic samples from Indian citizens. Once the data is collected, whole genome sequencing and analysis will be carried out.

The project is significant for a number of reasons. The data is expected to increase the understanding of diseases that are affecting the Indian population. This will play a major role in developing the predictive diagnostic markers. Different subpopulations of patients may respond to the same therapy differently. Predictive markers help in identifying the possible response from a particular subpopulation of patients to specific therapies. This will allow us to identify the patients who will most likely to benefit from a given treatment. At the same time, it will help in avoiding administering ineffective treatments to other patient groups, where the treatment will not have the intended effect. This will also form the foundation for the advancement of next-generation personalised medicine.

The information generated from the project can also be used in preventive medicine. For instance, population with more susceptible risk factors for a certain diseases can be identified, and necessary interventions at community level can be made for the preventive measure from the disease.

Further, the existing genome research is dominated by western countries. For instance, more than 95% of the genome samples on which research is carried out are based on the white Caucasian genome. These genomes are not representative of the overall global population. Moreover, the genetic diversity of the Indian population varies greatly given the long and diverse history of the Indian subcontinent. Hence, the Indian project aims to add to the available research in a significant way, as the scale and diversity of Indian population are huge and unique. For instance, though the initial migrations to the Indian subcontinent were from Africa, there were periodic migrations and intermingling of races throughout the history of the subcontinent. This is called 'horizontal diversity'. On the other hand, certain groups

practiced endogamy and restricted marriages outside that group. As a result, certain traits and diseases have passed within very specific groups. This is called 'vertical diversity'. Understanding and studying these diversities will act as the basis of personalized healthcare in the future.

The Genome India Project is a collaborative effort of 20 leading institutions. It is led by the Centre for Brain Research, Indian Institute of Science (IISC), Bengaluru. The data collection will be carried out through hospitals, where the investigators will collect blood samples from participants and add the information to biobanks.

What Is a Genome?

Genome, in simple terms, can be defined as all the genetic matter in an organism. It is an organism's complete set of DNA and all its genes. Hence, a genome contains within it all the information that are needed to build and maintain an organism.

Human Genome Project

In 2003, the Human Genome Project, an international project aimed at decoding the entire human genome, was completed. DNA molecules are made of paired strands. The human genome is an estimated to contain around 3 billion of base pairs, which form estimated 30,000 genes in a human body and reside in the 23 pairs of chromosomes. The final version of the human genome sequence is published by the International Human Genome Sequencing Consortium. The Human Genome Project is a collaborative effort between the United States, France, the United Kingdom, China, Japan, and Germany.

Human Microbiome Initiative

Human microbiome refers to the diverse communities of microorganisms present in the human body. These microorganisms play an important role in physiological processes, metabolism, and immune system in humans. Different types of microorganisms are present in human body based on factors such the organs in which they are located (different organs possess different microorganisms), genetics, age, dietary habits, and even geographic location. The detailed study of these microbes will lead to an increased understanding of a wide range of diseases and their effects.

The human microbiome initiative is a project launched by the Department of Biotechnology in 2019 that aims to collect the saliva, stool, and skin swabs from 20,000 Indians across various ethnic groups and geographical regions. The project aims to map the influence of diet, age, lifestyle, and geography on the gut microbiome in 17 different endogamous groups (groups that marry within themselves) across the country. The objectives of the project include:

- To generate baseline gut microbiome data

- To understand the relationship between diet and gut microorganisms
- To understand the association between Ayurvedic phenotype and microbiome.

Ayurvedic phenotype

In Ayurveda, a person's Prakriti, that is, a person's nature is determined by the proportion of three doshas called Vata, Pitta, and Kapha. These doshas are the primary functional energies in the human body. According to Ayurveda, the state of these doshas determine the health of an individual. If the three doshas are balanced, an individual is healthy. Any imbalance in the doshas causes ill health.

Each person is characterised by a predominant dosha type and accordingly, will exhibit different phenotypes. In other words, certain characteristics and diseases are associated with Vata, Pitta, or Kapha phenotypes, respectively. For instance, Vata Prakriti individuals are characterized by dry skin and hair and lean phenotypes. They are generally susceptible to fatigue, insomnia, nervous system-related disorders, etc. On the other hand, Pitta Prakriti individuals tend to develop inflammation-related disorders such as ulcers. The Kapha Prakriti individuals have a tendency to be heavy and are susceptible to obesity and respiratory disorders.

Ayurvedic healing hence focuses on treating the imbalances of doshas. The treatment is unique to each dosha type.

Brahma–The Indian Brain Template

BRAHMA is the name given to the Indian Brain template developed by scientists in 2020 based on a research study of two years. In simple terms, a brain template is like a map that provides a standard reference coordinate system to analyse the structure of the brain. The National Brain Research Centre initiated the project in 2018 and successfully completed the construction of the first high-resolution Indian population specific brain template in 2020.

The template is developed using the MRI scans of healthy Indians and shows intrinsic details of the anatomy of the Indian brain. So far, scientists have relied on the brain templates of other countries during brain surgeries, diagnosis, and treatment of brain-related disorders. There could be significant variations in the key brain regions among different racial types. Hence, several countries developed their own brain templates to serve as a reference point for effective surgeries and treatment. For instance, China and Canada have a brain template of their population. The development of Indian brain template, therefore, is expected to serve as a better guide to neuroscientists and surgeons.

Manav: Human Atlas Initiative

Manav—Human Atlas initiative aims to collate and present all the relevant macro and micro data with reference to the entire human body in a single place. The objective of the project is to provide reliable information at a single point to researchers, students, teachers and medical professionals. This will help improve our understanding of the working of the human body, trace causes of various diseases and changes to the tissues and cells at different stages of diseases and design better therapeutic agents to treat diseases.

MANAV is derived from the Sanskrit word 'Manav', which means Human. The Atlas would be created by mapping the molecular level details of each cell, tissue, and organ in the human body. In simple terms, all the relevant information will be sourced from existing scientific literature and public databases and presented in the Atlas. The project aims to understand and capture the information on human physiology in two stages: normal (healthy) and diseased stages. The final year students in the selected disciplines will be trained in the curation of information and annotation using specialised tools.

The project was launched in 2019 under public–private partnership by the Department of Biotechnology and Persistent Systems (a technology services private company), Indian Institute of Science Education and Research (IISER), Pune, and National Center for Cell Sciences (NCCS), Pune.

Practice Questions

1. Which of the following benefits may be reaped from transgenic crops?

1. Increased shelf life
2. Higher crop production
3. Higher nutritional value

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

2. Consider the following statements with reference to 'gene testing':

1. Gene testing can be used to determine a person's ancestry.
2. Gene testing may help in preventing genetic disorders.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

3. Which one of the following techniques can be used to establish the paternity of a child?

(a) Protein analysis
(b) Chromosome counting
(c) Quantitative analysis of DNA
(d) DNA fingerprinting

4. The application of biotechnology to make industrial processes more efficient is called:

(a) Green biotechnology
(b) Blue biotechnology
(c) White biotechnology
(d) Red biotechnology

5. Consider the following statements regarding stem cells:

1. In our day to day lives, stem cells regularly replace dead cells from our body tissues.
2. Stem cells help in understanding the occurrence of degenerative diseases.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

6. Consider the following statements regarding traditional plant breeding:

1. Traditional plant breeding cannot be carried among interspecies.
2. Traditional plant breeding is carried through recombinant DNA technology.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

7. The term 'Cirb Gaurav' is used in the context of:

(a) A cloned monkey offspring
(b) First cloned human offspring
(c) A cloned buffalo offspring
(d) First cloned sheep offspring

8. Which of the following are ex-situ bioremediation techniques:

1. Bioaugmentation
2. Biopile
3. Land farming

Select the correct answer using the codes given below:
(a) 1 and 2 only (b) 2 and 3 only
(c) 3 only (d) 1, 2, and 3

9. Consider the following statements regarding golden rice:
1. The golden yellow colour of the rice is due to the presence of high protein in the rice.
2. The golden rice is fortified with proteins in order to eliminate protein deficiency.

Which of the statements given above is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

10. Consider the following statements regarding cloning:
1. World's first cloned animal was Dolly, the sheep.
2. The first case of human cloning was recorded in Germany in 2004.

Which of the statements given above is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

11. Consider the following statements with regard to DNA analysis:
1. DNA fingerprinting has become an important test to establish the paternity and identity the criminals of rape cases.
2. Dried blood and semen are adequate for DNA analysis.

Which of the statements given above is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

12. The term 'virotherapy' refers to:
(a) A virus that is used to treat leukemia
(b) A medical treatment to kill foreign virus that may cause some disease
(c) A medical treatment that converts viruses into therapeutic agents
(d) A medical treatment that is used to cure any genetic disorder

13. Consider the following statements:
1. If scientists could locate and extract the DNA out of a lock of Einstein's hair, another Einstein could be produced by cloning.
2. The DNA extracted from the cell of an embryo at an early stage of development can be transferred to denucleated egg, which in turn can be implanted into the uterus of a surrogate mother to give birth to an identical offspring.

Which of the statements given above is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

14. Consider the following statements:
1. Phytomining is an approach in which mining is done with the help of plants.
2. Biosorption is an approach in which extraction of desired minerals from ores is done with the help of living organisms.

Which of the statements given above is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

15. Stem cell therapy (SCT) is not useful for the treatment of which one of the following ailments?
(a) Kidney-related ailments
(b) Hypertension
(c) Liver damage
(d) Vision impairment

16. The term 'biomimetics' is sometimes seen in the news with reference to:
(a) Implementation of concepts from nature to create new materials, devices, and systems.
(b) Use of rare earth metals to create artificial body parts which can function like real parts.
(c) Implementation of cloning technique to create exact replica of physical devices.
(d) Use of biotechnology principles in day-to-day life for a comfortable living.

17. With reference to the latest developments in stem cell research, consider the following statements:
1. The only source of human stem cells is the embryo at the blastocyst stage.
2. The stem cells can be derived without causing destruction to blastocysts.
3. The stem cells can automatically regenerate themselves.

Which of the statements given above is/are correct?
(a) 1 and 2 only (b) 1, 2, and 3
(c) 1 only (d) 3 only

18. With reference to 'biological engineering', consider the following statements:
1. It is an interdisciplinary area focusing on the application of engineering principles to analyse biological systems and solve problems related to biological systems.
2. Greater fundamental knowledge of biology and its potential applications are pre-requisites for biological engineering.

Which of the statements given above is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

19. With reference to the rDNA technology, consider the following statements:
1. The restriction enzymes attach themselves to a DNA base of the bacteria and restricts the DNA from being digested.
2. The modification enzymes derived from bacteria are used to cut a DNA at a particular location.

Which of the statements given above is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

20. Why is 'alkaline phosphatase' used in rDNA technology?
(a) To act as a vehicle to carry the required gene
(b) To prevent self-ligation

(c) To connect two DNA strands together
(d) To cut a DNA strand precisely

21. Consider the following statements with reference to CRISPR-Cas9:

1. CRISPR-Cas9 is a part of bacteria's immune system that protects it from viral infections.
2. CRISPR-Cas9 acts as a molecular scissors, and is used to cut DNA precisely.
3. The location at which CRISPR needs to cut, the DNA is specified by the RNA sequence of Cas9.

Which of the statements given above is/are correct?
(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2, and 3

22. Which of the following statements is/are **incorrect** with reference to the Genome India project?

1. Project Genome India aims to collect genome data from around 1,00,000 Indian citizens to carry out Indians specific genome sequencing.
2. India was a part of the Human Genome Project completed in 2003.
3. The Genome India Project is being led by the Indian Institute of Science, Bengaluru.

Select the correct answer using the codes given below:
(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2, and 3

23. Which of the following pairs is/are correctly matched?

Type of Food	**Fortified with**
1. Rice	Folic acid
2. Edible oil	Vitamin D
3. Salt	Iron

Select the correct answer using the code given below:
(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2, and 3

24. Which of the following pairs is/are **incorrectly** matched?

Project	**Focus area**
1. BRAHMA	The Human Atlas Initiative of India
2. MANAV	The Indian Brain Template
3. SAMRUPA	The Genome India Project

Select the correct answer using the codes given below:
(a) 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2, and 3

25. At the present level of technological advancement, which of the following statements is/are correct with reference to the organoids derived from stem cells?

1. The organoids can be derived from only embryonic stem cells but not from induced pluripotent stem cells.
2. Organoids can be used to study human immune responses to various infections such as Covid-19.
3. The organoids can exactly replicate the human immune system and completely replace the need for humans in clinical trials.

Select the correct answer using the codes given below:
(a) 2 only (b) 1 and 3 only
(c) 1 and 2 only (d) 1, 2, and 3

26. Consider the following statements:

1. The Genetic Engineering Appraisal Committee was formed under the provisions of the Environment Protection Act, 1986.
2. The GEAC functions as an advisory body under the Ministry of Agriculture.
3. The GEAC is responsible to grant approval for the cultivation of genetically modified crops.

Which of the statements given above is/are correct?
(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2, and 3

27. The process in which new materials and systems are created artificially by adapting the methods and systems found in nature is called

(a) Bioprospecting
(b) Biomimetics
(c) Bionics
(d) Bioinformatics

28. Which of the following genetically modified crops are presently not allowed for cultivation in India?

1. HT Bt cotton
2. Bt Mustard
3. Bt Brinjal
4. Bt Soyabean

Select the correct answer using the code given below:
(a) 2, 3, and 4 only (b) 1, 2, and 3 only
(c) 1, 3, and 4 only (d) 1, 2, 3, and 4

29. With reference to gene editing, consider the following statements:

1. DNA Ligase is the enzyme used to connect two strands of DNA together in gene editing.
2. Methylation is used to prevent self ligation in DNA molecules during gene editing.

Which of the statements given above is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

30. Which of the following is/are the benefits of the 'Genome India Project'?

1. The project will aid in developing personalised medicine in India.
2. The project aims to map the influence of diet, age, lifestyle, and geography on the gut microbiomes and the health of Indians.

Select the correct answer using the codes given below:
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

PERFECTING PAST PRELIMS

1. Mon 863 is a variety of maize. It was in the news for which of the following reasons? **(2010)**

(a) It is a genetically modified dwarf variety resistant to drought.
(b) It is a genetically modified variety that is pest-resistant.
(c) It is a genetically modified variety with ten times higher protein content than the regular maize crop.
(d) It is a genetically modified variety used exclusively for biofuel production.

2. Genetically modified 'golden rice' has been engineered to meet human nutritional requirements. Which one of the following statements best qualifies golden rice? **(2010)**

(a) The grains have been fortified with genes to provide three times higher grain yield per acre than other high-yielding varieties.
(b) Its grains contain pro-vitamin A, which upon ingestion is converted into vitamin A in the human body.
(c) Its modified genes causing the synthesis of all the nine essential amino acids.
(d) Its modified genes cause fortification of rice grains with vitamin D.

3. A genetically engineered form of brinjal, known as the Bt-brinjal, has been developed. The objective of this is **(2011)**

(a) To make it pest-resistant
(b) To improve its taste and nutritive qualities
(c) To make it drought-resistant
(d) To make its shelf life longer

4. What are the reasons for the people's resistance to the introduction of Bt brinjal in India? **(2012)**

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 an adverse impact on health.
4. There is some concern that the introduction of Bt brinjal may have an adverse effect on biodiversity.

Which of the statements given above is/are correct?

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

5. With reference to 'stem cells', frequently in the news, which of the following statements is/are correct? **(2012)**

1. Stem cells can be derived from mammals only.

2. Stem cells can be used for screening new drugs.
3. Stem cells can be used for medical therapies.

Select the correct answer using the codes given below:
(a) 1 and 2 only (b) 2 and 3 only
(c) 3 only (d) 1, 2, and 3

6. Other than resistance to pests, what are the prospects for which genetically engineered plants have been created? **(2012)**

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 stations.
4. To increase their shelf life.

Select the correct answer using the codes given below:
(a) 1 and 2 only (b) 3 and 4 only
(c) 1, 2 and 4 only (d) 1, 2, 3, and 4

7. Recombinant DNA technology (Genetic Engineering) allows genes to be transferred: **(2013)**

1. Across different species of plants.
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

8. Mycorrhizal biotechnology has been used in rehabilitating degraded sites because mycorrhiza enables the plants to: **(2013)**

1. Resist drought and increase absorptive area.
2. Tolerate extremes of pH.
3. Resist disease infestation.

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

9. Consider the following techniques/ phenomena:

1. Budding and grafting in fruit plants
2. Cytoplasmic male sterility
3. Gene silencing

Which of the above is/are used to create transgenic crops? **(2014)**
(a) 1 only (b) 2 and 3
(c) 1 and 3 (d) None

10. The Genetic Engineering Appraisal Committee is constituted under the: **(2015)**

(a) Food Safety and Standards Act, 2006.
(b) Geographical Indications of Goods (Registration and Protection) Act, 1999.
(c) Environment (Protection) Act, 1986.
(d) Wildlife (Protection) Act, 1972.

11. What is the application of somatic cell nuclear transfer technology? **(2017)**

(a) Production of biolarvicides.
(b) Manufacture of biodegradable plastics.

(c) Reproductive cloning of animals.
(d) Production of organisms that are free of diseases.

12. With reference to agriculture in India, how can the technique of 'genome sequencing', often seen in the news, be used in the immediate future? **(2017)**

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

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

13. In the context of the developments in bioinformatics, the term 'transcriptome', sometimes seen in the news, refers to **(2016)**

(a) A range of enzymes used in genome editing.
(b) The full range of mRNA molecules expressed by an organism.
(c) The description of the mechanism of gene expression.
(d) A mechanism of genetic mutations taking place in cells.

14. With reference to the Genetically Modified mustard (GM mustard) developed in India, consider the following statements: **(2018)**

1. GM mustard has the genes of a soil bacterium that give the plant the property of pest resistance for a wide variety of pests.
2. GM mustard has the genes that allow plant cross-pollination and hybridization.
3. GM mustard has been developed jointly by the IARI and Punjab Agricultural University.

Which of the following statements given above is/are correct?

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

15. With reference to the recent developments in science, which one of the following statements is not correct? **(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.

16. 'RNA interference (RNAi)' technology has gained popularity in the last few years. Why? **(2019)**

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 viral pathogens.

Select the correct answer using the codes given below.

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

17. Consider the following statements: **(2020)**

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

Which of the statements given above is/are correct?

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

18. With reference to recent developments regarding 'Recombinant vector Vaccines' or DNA vaccines, consider the following statements: **(2021)**

1. Genetic engineering is applied in the development of these vaccines.
2. Bacteria and viruses are used as vectors.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

19. Bollgard I and Bollgard II technologies are mentioned in the context of **(2021)**

(a) Clonal propagation of crop plants
(b) Developing genetically modified crop plants
(c) Production of plant growth substances
(d) Production of biofertilizers

☑ ANSWER KEYS

Practice Questions

1. (d)	**2.** (c)	**3.** (d)	**4.** (c)	**5.** (c)
6. (d)	**7.** (c)	**8.** (b)	**9.** (d)	**10.** (a)
11. (c)	**12.** (c)	**13.** (b)	**14.** (a)	**15.** (b)
16. (a)	**17.** (d)	**18.** (c)	**19.** (d)	**20.** (b)
21. (a)	**22.** (a)	**23.** (d)	**24.** (d)	**25.** (a)
26. (c)	**27.** (b)	**28.** (d)	**29.** (a)	**30.** (a)

Perfecting Past Prelims

1. (b)	**2.** (b)	**3.** (a)	**4.** (c)	**5.** (b)
6. (c)	**7.** (d)	**8.** (d)	**9.** (b)	**10.** (c)
11. (c)	**12.** (d)	**13.** (b)	**14.** (b)	**15.** (a)
16. (a)	**17.** (d)	**18.** (c)	**19.** (b)	

Solutions

Practice Questions

2. (c) Statement 1 is correct: Gene testing or genetic genealogy involves the examination of DNA variations which provide clues about where a person's ancestors might have come from.

Statement 2 is correct: Genetic testing is a type of medical test that identifies changes in genes. The results of a genetic test can confirm or rule out a suspected genetic condition or help determine a person's chance of developing or passing on a genetic disorder.

5. (c) Statement 1 is correct: Stem cells are responsible for the repair of damaged tissues, and the replacement and regeneration of tissues that turn over rapidly, such as the skin, blood, or the lining of the intestine.

Statement 2 is correct: Embryonic stem cells possess the property of pluripotency i.e., they have the potential to divide into different cell types. By isolating specific cell types related to the degenerative diseases, the diseases can be studied and in the long-run may also be cured.

6. (d) Statement 1 is incorrect: Traditional plant breeding, unlike animal breeding, can be carried inter-species.

Statement 2 is incorrect: Traditional plant breeding involves techniques like grafting, natural pollination, etc. Recombinant DNA technology is used to create transgenic or genetically modified varieties.

8. (b) Biopiles and land farming are ex-situ bioremediation techniques.

Bio augmentation is in situ biological treatment, involving mainly microbes, to clean up the hazardous contaminants in soil and water.

9. (d) Statement 1 is incorrect: The yellow colour of 'golden rice' is due to the presence of β-carotene (pro-vitamin A) and xanthophylls (yellow-coloured pigment).

Statement 2 is incorrect: Golden rice is rich in β-carotene (pro-vitamin A) that is effective in curtailing vitamin A deficiency (VAD). It is not fortified with proteins.

13. (b) Statement 1 is incorrect: A lock of hair is mostly comprised of protein and not cellular material, so it will not carry any human genomic DNA.

Statement 2 is correct: This is the process used in cloning.

14. (a) Statement 2 is incorrect: Biosorption is a property of certain types of inactive, dead, microbial biomass to bind and concentrate heavy metals from even very dilute aqueous solutions.

15. (b) Hypertension is not related to particular damaged cell or tissue. It is the medical condition related to the overall functioning of a body.

17. (d) Statement 1 is incorrect: Stem cells can also be obtained from body cells (bone marrow, adipose tissue, blood, etc.) and other sources such as umbilical cord.

Statement 2 is incorrect: Stem cells can be obtained from the blastocyst by only removing the embryo from the womb and taking the cells which were destined to form tissues of the growing foetus.

19. (d) Statement 1 is incorrect: The modification enzymes attach themselves to a DNA base of the bacteria and prevents the DNA from being digested.

Statement 2 is incorrect: The restriction enzymes derived from bacteria are used to cut a DNA at a particular location.

20. (b) The vector (vehicle which carries required DNA sequence) is treated with alkaline phosphatase to prevent self-ligation.

21. (a) Statement 3 is incorrect: The location at which Cas9 needs to cut, the DNA is specified by the RNA sequence of CRISPR.

22. (a) Statement 1 is incorrect: Project Genome India aims to collect genome data from around 10,000 Indian citizens, not a lakh.

Statement 2 is incorrect: The Human Genome Project is a collaborative effort between the United States, France, the United Kingdom, China, Japan and Germany.

23. (d) Double Fortified salt is fortified with iron along with iodine.

24. (d) Pair 1 is incorrectly matched: BRAHMA project is to identify Indian Brain Template.

Pair 2 is incorrectly matched: MANAV is the Human Atlas Initiative.

Pair 3 is incorrectly matched: SAMRUPA is the world's first cloned buffalo calf by the National Dairy Research Institute.

25. (a) Statement 1 is incorrect: Organoids can be derived from induced pluripotent stem cells as well.

Statement 3 is incorrect: One of the major limitations of organoids is that they may not replicate the exact human immune response. As they are grown in controlled environment, their immune levels are lower than the acquired immunity levels exhibited by the actual human organs.

26. (c) Statement 2 is incorrect: The GEAC functions under the Ministry of Environment, Forest and Climate Change.

28. (d) The HT Bt stands for Herbicide-tolerant Bt Cotton. It adds another genetic modification to the Bt cotton crop to make the crop resistant to herbicide. As a result, farmers can spray herbicides to kill the weeds without harming the cotton plant. However, GEAC has not approved the use of HT Bt cotton in India.

29. (a) Statement 2 is incorrect: Methylation is part of the self defense mechanism in bacteria. DNA fragments are treated with an enzyme called alkaline phosphatase to prevent self ligation in DNA molecules during gene editing.

30. (a) Statement 2 is incorrect: The Human Microbiome Initiative (not the Genome India project) aims to map the influence of diet, age, lifestyle, and geography on the gut microbiomes.

Perfecting Past Prelims

1. (b) MON 863 is a genetically modified variety of maize. It was in the news because it was genetically modified to resist pest.

4. (c) Statements 1 and 2 are incorrect.

Statement 3 is correct: Bt toxin trait works against certain insects that have alkaline pH digestive tract. A similar effect was feared in the digestive tracts of higher mammals such as humans.

Statement 4 is correct: It is feared that cross pollination of Bt gene with the local weeds may produce a new variety of super weeds that would be immune to weedicides.

5. (b) Statement 1 is incorrect: Stem cells can be derived from both plants and animals.

6. (c) Statement 3 is incorrect: GM plants are not modified to grow and photosynthesise in spaceships and space stations. There is an absolute absence of gases in space, which are the primary requirements to carry out photosynthesis.

7. (d) Statement 1 is correct: Genetic engineering has enabled the transfer of genes across different plant species such as daffodil plant gene in golden rice.

Statements 2 and 3 are correct: The Bt gene of *Bacillus thuringiensis* is transferred to various crops for making them pest-resistant. This signifies both gene transfer from animals to plants and from lower organisms to higher ones.

9. (b) Statement 1 is incorrect: Budding and grafting in fruit plants are traditional methods of breeding, and are not used to create transgenic crops.

14. (b) Statement 1 is incorrect: Unlike most GM crops, GM Mustard do not have genes of soil bacterium. It is produced by cross pollinating Indian mustard with East European mustard.

Statement 3 is also incorrect: GM Mustard has been prepared by researchers of Delhi University.

Statement 2 is correct.

15. (a) Functional chromosomes can be created by joining segments of DNA taken from cells of different species.

This question can be solved through elimination technique.

Let us start from option (d). It is easiest. The statement given in answer option can be eliminated on the basis of cloning technique. In the process of cloning, cells taken out from plants and animals undergo cell division in laboratory petri dishes.

Options (b) and (c) can also be eliminated. Synthetic biology is used to create pieces of artificial functional DNA. It can also be used to replicate DNA outside a living cell.

16. (a) 1, 2, and 4

Statement 1 is correct: As RNA transcribes genetic information from the DNA found in a cell's nucleus and then carries this information to other cell organelles, RNAi is used in developing gene silencing therapies.

Statement 2 is correct: Cancer is abnormal growth of body cells which is related to DNA present in them. As DNA are expressed through RNA, RNAi can be used in developing therapies for-the treatment of cancer.

Statement 3 is incorrect: Genetic information has not been intrinsically related to our hormone system. Thus, RNAi cannot be used to develop hormone replacement therapies.

Statement 4 is correct: RNA can impact expression of DNA which may make plant vulnerable to viral pathogens. Thus, RNAi can be used to produce crop plants that are resistant to viral pathogens.

17. (d) 1, 2 and 3

Statement 1 is correct: Genetic changes are possible in parent cells. Thus, Genetic changes can be introduced in the cells that produce eggs or sperms of a prospective parent.

Statement 2 is correct: A person's genome can be edited before birth at the early embryonic stage.

Statement 3 is correct: Human induced pluripotent stem cells can be injected into the embryo of a pig. This statement is based on a recent successful scientific experiment and is thus, part of current affairs.

CHAPTER

22 Data Security

1 DATA

The Data Protection Bill 2019 defines data as "information, facts, concepts, opinions, or instructions in a manner suitable for communication, interpretation, or processing by humans or by automated means". In other words, data is a variety of information that can be used for different purposes.

Data can be online or offline. In recent times, data acquired significance with the internet revolution. Data is being generated at an unprecedented speed and scale as people undertake online transactions, communicate with each other using social media, file taxes online, etc. Further, governments also hold significant amounts of data of their citizens.

The Economic Survey 2018-19 classifies the data held by the Government of India under four categories:

1. **Administrative data:** Administrative data refers to data collected as part of the day-to-day administrative activities of the government and is majorly used for non-statistical purposes. The data such as birth and death records, land and property registrations, tax records, crime reports, vehicle registrations, movement of people across national borders, etc., are examples of administrative data. The data collected by the government to evaluate the effectiveness of welfare schemes also forms a part of administrative data.
2. **Survey data:** Survey data refers to data collected through periodic surveys by the government, mainly for statistical purposes. For instance, the Census data collected by the government once in a decade is called survey data. In these data, the identity of the participants is not reported and is considered irrelevant. In other words, the overall measures such as rural-urban population, sex ratio, etc., are reported. But the individual data (the name or address of the person living in a village or a city) is stored at the backend securely.
3. **Transactions data:** Transactions data refers to the data collected on the basis of financial transactions made by individuals using online payment services. For instance, transactions made using Unified Payment Interface (UPI) can be identified as transactions data.
4. **Institutional data:** Institutional data refers to the data maintained by public institutions. For instance, medical records of patients in government-run hospitals, student details in state-run colleges, fall under the category of institutional data.

The private sector also holds a significant amount of data. For instance, every time an individual uses a search engine, sends email, talks on digital platforms, makes purchases, pays bills, makes appointments, and so on, data sets are generated. This data may be harnessed by the private sector in a beneficial way, such as to improve the delivery of services to individuals.

On the other hand, possibilities exist that these data may be used to manipulate individuals' behaviour or shared with third parties without the individuals' knowledge or consent. It becomes important to ensure that the data is protected, transferred, and analyzed only in legal and ethical ways. To ensure this, data protection laws and guidelines are issued by the governments.

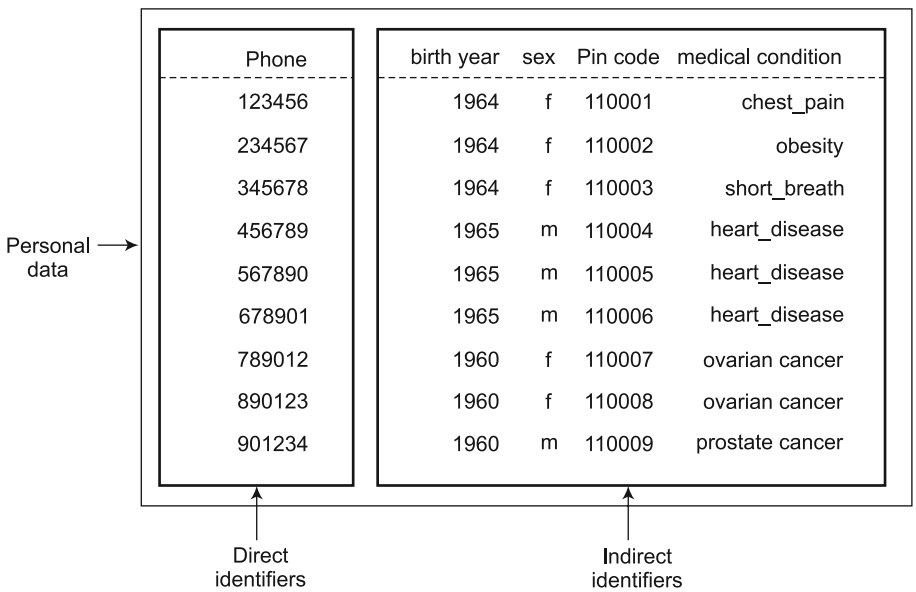
Terms Related to Data Ownership

Every time data is generated or collected by public or private entities, the ownership of the data needs to be established. In other words, it is important to identify who can use the data and in what ways.

Data principal: The natural person to whom the data is related to is known as the Data principal. In other words, the collected data is that of the Data Principal.

Data Fiduciary: Data fiduciary is the individual or entity who determines the purpose and means of processing personal data collected from a Data principal. In other words, Data fiduciary decides what data needs to be collected, why and how it needs to be processed. The data fiduciary may process the data by itself or use the services of a third party to process this data.

Personal data: The data related to any characteristic, trait, or an identity feature of an individual and can be used directly or indirectly to identify such a person is called 'personal data' of an individual. The direct identifiers refer to information that can be used to explicitly identify a person. Name of an individual, biometric data, aadhaar number, are some of the examples of direct identifiers.



Indirect identifiers, also called quasi identifiers, are information that when combined with additional data, can be used to identify an individual. Medical records, financial information, date of birth, are some of the examples of indirect identifiers.

Data Processor: Data processor refers to the third party (individuals or entities) that processes the personal data of the data principal on behalf of the data fiduciary.

Official identifier: In some cases, data of an individual or an entity is used to establish or verify identity. Such data, which is recognised by law as an identifier is called an official identifier. In other words, an official identifier refers to a number, code, or any other data, which is assigned, in accordance with law, to a data principal to be used for identification purposes. Some of the examples of official identifiers include Permanent Account Number (PAN), Aadhaar, and Electors Photo Identity Card (EPIC).

At many instances, one needs to establish the identity of self using official identifiers. This process is referred to as authentication.

Aadhaar Authentication

Aadhaar authentication refers to the process in which Aadhaar Number and attributes such as biometrics are submitted to a Central Identities Data Repository (CIDR) and verified. The CIDR verifies the information on the basis of data available with it. The service is supported by the Unique Identification Authority of India (UIDAI), a statutory body established to provide a Unique Identity (Aadhaar) to all Indian residents.

The Aadhaar authentication service responds with a yes/no response and does not reveal any personal data of the individual to the parties that requested authentication. Yes response implies that the identity of the individual is verified, and No response means that the identity is not verified. The authentication is done using factors such as biometric data, Personal Identification Number (PIN), and One Time Password (OTP). These factors that are used to verify the identity are called authentication factors. The biometric data that can be used for authentication include fingerprints, iris impressions, or face recognition. At present, face authentication is not supported by UIDAI.

Any entity such as banks, government departments, private organizations, that wish to use Aadhaar authentication needs to register with the Aadhaar authentication server. Further, to enable authentication, these entities use an Application programme interface (API). API is a software protocol that helps connect different softwares or hardware and softwares. In other words, it defines how the interactions happen between two or more platforms. Aadhaar authentication API enables an entity to connect with the Aadhaar servers to establish the identity of an individual.

2 MISUSE OF DATA

Data protection becomes important to avoid possibilities of misusing individuals' data. Certain types of data misuse, such as stealing information or carrying out unauthorised transactions, are punishable by

law. These offenses are considered cybercrimes, and legal provisions exist to punish the criminals. The cybercrimes such as hacking, E-mail spoofing, phishing, cyberstalking are discussed in detail in Chapter 11 (Information Technology).

However, misuse of data may not directly cause harm (physical or financial) to individuals or entities immediately. Misuse can happen in subtle ways. For instance, data is regularly analysed by public and private entities to influence and manipulate the behaviour of individuals. One of the challenges faced by policymakers across the globe is to regulate such use of data that leads to influence and manipulation of individuals' behaviour.

For instance, algorithms may be used to manipulate the users' voting and shopping behaviours in a subtle manner without the users' knowledge. In extreme cases, algorithms may be used by terrorist organisations to recruit gullible and vulnerable individuals or cause communal disharmony.

To predict or manipulate an individuals' or groups' behaviour, data is analysed on the basis of their online activities. Various techniques are used for this purpose, such as data profiling and psychographics.

Data Profiling

The process in which personal data is processed to analyse behaviour patterns, interests, or attributes of a data principal is called data profiling. Data profiling can also be used to predict behaviours of individuals.

For instance, one can categorise shoppers on the basis of their age group, gender, occupation, income level, and choice preferences to send personalised advertisements or offers.

Psychographics

Psychographics refers to psychological profiling of a target group of individuals to understand them better. Psychographics can be used by a wide range of public and private organisations, political parties, and governments for different purposes. For instance, governments can use psychographics to customise their welfare schemes, companies to make better sales pitches for their products, and political parties to tailor their political campaigns.

Data generated by users online can be used for psychographics. For instance, a study showed in 2013 that sensitive personal attributes of an individual such as political views can be predicted by data such as individuals' "Likes" on Facebook. A company called Cambridge Analytica was accused of profiling millions of users and creating targeted ad campaigns to manipulate political views of people based on their activities on facebook.

Consequences of Data Profiling and Psychographics

Data Profiling and Psychographics are often used to predict, influence, and manipulate individuals. Some of the particular issues which arise are discussed as follows:

Filter Bubble

The term 'filter bubble' was coined by Eli Pariser, an internet activist. The term refers to a phenomenon in which an internet user is exposed to selective online content. The term is used in context of social media

giants that they 'filter' information and create a 'bubble' in which the user is confined. An algorithm tracks the attributes of an individual such as his likes, people he follows or the ads that he clicks on, etc. In other words, the algorithm identifies how the user is spending his time on the internet. This analysis is used to filter information, which the user tends to ignore or skip or seems disinterested while browsing.

This means that instead of allowing a free flow of information, the filter bubble selectively hides information and displays only a part of it. In essence, algorithms create a unique universe of information for an individual.

Why is Filter Bubble Harmful?

The phenomenon of a Filter bubble is used by internet companies to show a user the content that will more likely make the user click on, comment, or share, to generate traffic and increase the ad revenues. It increases the average time spent by a user on the internet, and in extreme cases, lead to internet addiction. Further, the user may not be aware that he is being shown only selective content.

Moreover, the filter bubble skews the online information to represent specific ideologies and views based on an individual's social, cultural, and political ideologies. If an individual clicks on something because he believes it to be true, a filter bubble ensures that he receives similar information most of the time. As a result, the individual will only access information that reconfirms his preconceived notions and biases. This may lead to a false sense of being correct. In other words, the person not only feels that his view is right but also thinks that everyone agrees with his view.

Echo Chamber

Echo chamber refers to an environment in which an individual encounters opinions or information that reinforce and reflect one's own opinions and ideas. In some cases, echo chambers may also be used to create and spread misinformation. Though the terms echo chambers and filter bubbles are used interchangeably, there is a slight difference between the two.

Echo chamber is the result of overexposure to a particular type of news that one likes and agrees with. It distorts the perception of reality to suit individuals' likes. Filter bubbles use algorithms to filter news that one dislikes or disagrees with. This narrows down the exposure to opposing views and news.

While echo chambers can be a result of different processes (both offline and online), filter bubbles are a result of algorithmic filtering. For instance, one may choose to watch a particular news channel or move in circles with specific viewpoints. This forms an echo chamber. When an algorithm is used to expose individuals to specific viewpoints, it becomes a filter bubble. In other words, echo chambers are wider in scope, and filter bubbles can be seen as a means to echo chambers.

Cookies and Data Privacy

Cookies refer to messages that a web server passes on to the web browser when an individual visits a website. These messages are then stored by the browser in small files called cookie.txt. The browser passes these messages back to the server when one visits the website again.

Use of cookies: Cookies are used to enhance the user experience when visiting a website. A cookie sent by the server to the web browser acts as an identification card. When the user visits the website again, the browser passes the cookie back to the server. As a result, a user's information and preferences are stored, and the webserver need not request the same information again. Further, cookies help to provide personalised web pages based on users' preferences. For instance, if a user likes fictional novels by a particular author, similar novels would be shown by the website to the user.

Cookies are classified into different types on the basis of their use:

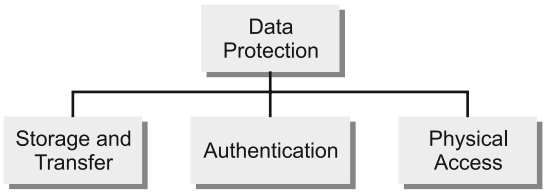
1. **Session cookies:** Session cookies are cookies used by e-commerce websites such as Amazon or Flipkart. These cookies are valid for a particular session and expire when the browser is closed. They allow users to add items and keep them in the shopping cart.
2. **Permanent cookies:** Permanent cookies are cookies that operate even after the browser is closed. These cookies remember the details such as username and passwords. These details need not be entered every time an individual uses a website.
3. **Third-party cookies:** Third-party cookies are cookies installed by third parties to track data related to an individual across websites. For instance, if an individual searches for a particular information on google, advertisements related to that product may pop up when the user is surfing the internet. Facebook, YouTube, Google, and Twitter, are some of the websites that use third party cookies.

When cookies are used as a secure and convenient way to transfer information from one session to another session on the same website, they don't present a threat to user's privacy. On the other hand, third-party cookies can pose a risk to privacy as they make it easier for unknown third parties to track individuals across different websites.

To address these privacy concerns, social media giants have announced that they will gradually phase out support for third-party cookies.

3 DATA PROTECTION

To minimise the misuse, data needs to be protected from unauthorised access, transfer, and usage. The protection is needed in all stages of data processing-collection, transfer, and storage. Data protection techniques such as encryption are used to ensure that data is stored safely. Personal data of the individuals should be protected from unauthorised access. Authentication is used to make sure that data is accessed only by desired users or entities. Further, it is also important to ensure that data is stored at safe physical locations (servers). Some of the measures used to ensure data protection are discussed below:



Methods of Safe Data Storage and Transfer

Data fiduciaries and Data processing companies need to ensure that the collected data is stored properly. Further, measures should be taken to ensure that the data does not reveal sensitive personal information of the data principal to unauthorised users. The following data protection techniques are used for this purpose.

Anonymisation: Anonymisation refers to the process of converting personal data to such a form where it cannot be used to identify the data principal. The process of anonymisation is irreversible, i.e., once the data has been anonymised, it cannot be processed back to establish the identity of data principals.

In other words, though the data belongs to individuals, one cannot identify the actual individuals whose data are under purview. For instance, data related to the different stages of progression of a disease of an individual can be anonymised. Data collected from different individuals can then be used in medical research.

De-identification: De-identification refers to the process of removing identifiers from personal data in such a way that the data cannot be used to identify the data principal. This is done by removing identifiers from personal data or replacing the identifiers with fictitious names or codes. The process of replacing the original data identifiers with artificial identifiers is also known as pseudonymisation.

The fictitious name or code is unique to every piece of data. However, it cannot be used to directly identify the individual; it can still be used to identify the individual by reversing the process of de-identification. In other words, unlike anonymisation, de-identification is reversible.

ID	First name	Last name	Age	Aadhar No.
1111	Gurdeep	Kaur	35	123456789012
1112	Shyam	Manick	59	234567890123
1113	Shubham	Singla	38	345678901234

Pseudonymized data

ID	First name	Last name	Age	Aadhar No.
1111	H0Tl9q	B0fq	35	123-XX-XXX
1112	H0h2f	Orf3yTT	59	234-XX-XXX
1113	i0xx6oT	F2Tp	38	345-XX-XXX

Anonymized data

ID	First name	Last name	Age	Aadhar No.
NA	NA	NA	35	NA
NA	NA	NA	59	NA
NA	NA	NA	38	NA

Re-identification: Re-identification refers to the process of reversing de-identification. This can be done by replacing the fictitious code with the original information or removing the masking on identifiers.

Data Protection Using De-identification

De-identification is the most commonly used method of data protection. It alters data, specifically the direct identifiers, to protect an individual's privacy. The following techniques are used to generate de-identified data:

- **Data encryption:** Encryption refers to a process of hiding sensitive data using a code, which is protected by an encryption key. In other words, encryption converts data into a form that can be accessed only by people or a system with a secret key. This secret key that can decrypt the message (convert the encrypted message into a readable message) is called the decryption key. Any other person who does not have a decryption key will not be able to read or understand the message. Moreover, during the transit of the data from one system to another, as the data is in encrypted form, no third person will be able to access this data.

  Different types of encryption schemes are used- symmetric, asymmetric, and hybrid schemes of encryption.

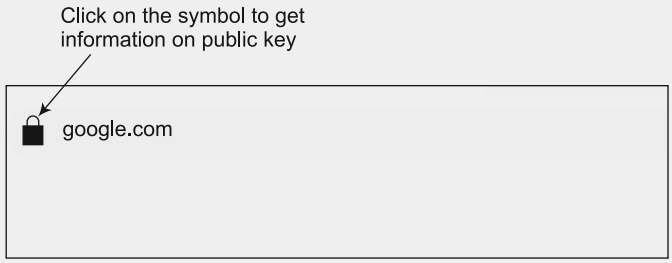
- Symmetric encryption is a type of encryption where a single secret key is used to encrypt and decrypt information. This secret key is to be shared between both entities, sending and receiving information. The sending entity uses it to encrypt the information, and the receiving entity uses the same key to decrypt information. Symmetric encryption is fast, efficient, and consumes lesser processing power compared to asymmetric encryption. Hence it is used in applications that involve bulk encryption of data.

- Asymmetric encryption is a type of encryption where instead of a single key, a pair of keys are used. A public key and private key pair are used to encrypt and decrypt messages. These two keys are different but form a pair; one encrypts and the other decrypts data. This means a public or private key is used to encrypt messages, and a private or public key is used to decrypt data. In other words, if a public key is used to encrypt the data, a private key is used for decryption or vice versa. However, asymmetric encryption uses higher processing power and takes more time. Hence, in most cases, a combination of both symmetric and asymmetric encryption is used. This is called hybrid encryption.

Asymmetric Encryption on Https webpages

The Https webpages use asymmetric encryption to establish a secure connection. Https stands for Hypertext Transfer Protocol Secure. It is used to establish a secure connection with the server over the internet. This means that when a user visits a website, the browser of the user establishes an asymmetric encrypted connection with that website.

How is secure connection established? The browser uses the public key to encrypt the data. The browser gets this public key from a data file hosted on the website's server. This data file is also known as a Secure Sockets Layer or Transport Layer Security SSL/TLS certificate. Websites with this certificate, that is https websites, follow the SSL or TLS cryptographic protocols to transfer data across servers, users, applications and systems. One can see the public key by clicking on the lock symbol before the Uniform Resource Locator (URL) of the website (URL is the address of a file or a specific webpage on the Internet).



Handshake refers to the process where a connection is established between the browser and the web server. During the connection, information is exchanged between the user browser and the web server. The public key encrypts the information a user browser sends to the website. The company that operates the website has a private key used to decrypt the message from its end.

Data shuffling: Shuffling refers to switching the identifiers within a column to disassociate them with the original data principal. For instance, in the tables below, the values in the columns 'First Name' and 'Aadhar Number' are interchanged. In data shuffling, the values in the data sets are real. However, they are assigned to wrong data principals.

ID	First Name	Last Name	Age	Aadhar No.
112	Gurdeep	Kaur	35	123456789012
113	Shyam	Manick	55	234567890123
114	Shubham	Singla	18	345678901234

Data Shuffling

ID	First Name	Last Name	Age	Aadhar No.
112	Gurdeep	Singla	35	234567890123
113	Shyam	Kaur	55	345678901234
114	Shubham	Manick	18	123456789012

Data suppression: Data suppression refers to removing sensitive data fields from the data set. For instance, direct identifiers such as name, phone number, are removed from the data. Along with direct identifiers, information that may be used to indirectly identify the individuals is also suppressed. For instance, if a public report is released with details such as student scores, data fields below a specific field value are suppressed. In the example below, school A only has ten students. Such low values make it easy to identify the schools and the individual scores of the students. In such cases, data is suppressed.

School Name	No. of students who appeared for board exam	% of Students scored above 90%	% of Students scored below 40%
A	10	10%	50%
B	1000	5%	70%
C	1100	4%	60%

Data Suppression

School Name	No. of students who appeared for board exam	% of Students scored above 90%	% of Students scored below 40%
A	*	10%	50%
B	1000	5%	70%
C	1100	4%	60%

Data redaction: Data redaction refers to masking out parts of column values. The data is either blackened out or filled with unidentifiable symbols, as shown below. For instance, when one enters details such as credit card information on e-commerce websites, the card details are redacted, and the middle digits of the credit card number are replaced with the symbol 'x'. The credit card number may be stored as a combination of the number and symbols, 1234xxxxxxxx2314. If someone tries to steal information from the company's server, they will receive the information in a redacted form, which cannot be used to make any transactions.

ID	First name	Last name	Age	Aadhar No.
1111	Gurdeep	Kaur	35	123456789012
1112	Shyam	Manick	59	234567890123
1113	Shubham	Singla	38	345678901234

Data Redaction

ID	First name	Last name	Age	Aadhar No.
[redacted]	Gurdeep	Kaur	35	XXX-XX-XXX
[redacted]	Shyam	Manick	59	XXX-XX-XXX
[redacted]	Shubham	Singla	38	XXX-XX-XXX

Data generalisation: Data generalization refers to the process of generalizing an identifier in such a way that it cannot be used to identify a person. For instance, a value range may be used in place of a specific numerical value to remove the exact identifer from the data set. In the table below, the exact age is replaced by a range.

ID	First Name	Last Name	Age	Aadhar No.
112	Gurdeep	Kaur	35	123456789012
113	Shyam	Manick	49	234567890123
114	Shubham	Singla	18	345678901234

Data Generalization

ID	First Name	Last Name	Age	Aadhar No.
112	Gurdeep	Kaur	(25-55)	123456789012
113	Shyam	Manick	(25-55)	234567890123
114	Shubham	Singla	(25-55)	345678901234

Generating synthetic data: Machine learning models can create a new dataset that mimic the original data. This new artificial data mimics the properties and removes the original identifiers from the data set. Instead of masking or altering original data, completely new data is created.

Safe Physical Storage

Data is stored in a physical space called servers and can be transferred across countries using cables. Data should be stored in secure servers, and one needs to ensure that the data does not fall in the hands

of criminals, terrorists, or unauthorised users who may misuse it. Further, cross-border data transfers from one country to another are regulated by the governments so that the personal data of a country's residents do not leave the country. Data localisation guidelines are released by the governments to prevent the storage and transfer of data outside their geographical boundaries.

Data Localisation

The physical attributes of data, that is, where it is stored, sent, or converted, are known as data flows. Data localisation aims to control these data flows.

Data localisation is a concept that mandates that the personal data of a country's residents should be stored and processed in that country only. Government may frame laws and guidelines to restrict the flow of data outside the country. At present, there is no global treaty to govern the transfer of data across different countries. Cross-border data transfer is governed by bilateral treaties signed by the countries.

In India, RBI issued a circular in 2018, mandating that the payment data related to transactions made by Indian residents would be stored only in India.

Authentication

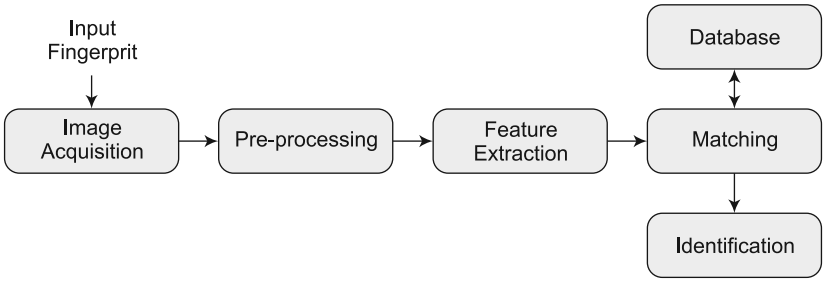
Authentication is done to ensure that data is accessed only by the authorised individuals. Biometric authentication is one of the modes of authentication in which biological attributes that are unique to an individual are used to verify identity. Biological traits such as fingerprints, retina, iris, and face are used for authentication.

Fingerprint Authentication

Fingerprint authentication, as the name indicates, uses one or more of an individual's fingerprints to verify his identity. It is a biometric authentication that compares an individual's fingerprint with a stored fingerprint template to verify one's identity.

The following steps are used in fingerprint authentication:

1. **Enrollment:** This is the initial step of setting up an authentication system. In this, an individual's fingerprints are scanned and stored in a coded form on a secure database.
2. **Verification:** Verification involves scanning an individual's fingerprint and comparing it with the record in a stored database. The following are the steps involved in the verification process: Image acquisition, pre-processing, feature extraction, matching, and identification.
   a. Image acquisition: A scanner is used to take an individual's fingerprint. This process is called image acquisition.
   b. Image Pre-processing: In this step, the images are processed to improve their quality.
   c. Feature extraction involves identifying the peculiar details of the fingerprints.
   d. The obtained peculiar details are then matched with the template stored in the existing database. If the details match with the information stored in the database, the verification is done.



Retinal Scan Authentication

A retinal scan uses the unique pattern on an individual's retina blood vessels to verify his identity. A retinal scan is different from Iris recognition.

Retina is a thin tissue of nerve cells located in the back of an individual's eye. These nerve cells receive and organise visual information. Small blood vessels called capillaries supply retina with blood. The arrangement of these capillaries is complex and is unique to a person. Fingerprints are influenced by genetics, but retinal patterns are not. Hence, in certain rare cases, identical twins may have similar fingerprints. But the retinal patterns are different even for identical twins.

Retinal patterns of an individual do not change with time. However, in certain cases of retinal degenerative disorders, diabetes or glaucoma (an eye condition that damages the optic nerve), the retinal patterns may change.

Process of Retinal scan: Retinal scan involves scanning an individual's eye using a beam of low energy infrared light. The blood vessels of the retina absorb more light than the surrounding tissue. The amount of reflection of light varies on the basis of the arrangement of these blood vessels. The pattern of the reflection is converted into a code, and then stored in a database.

When the same individual's retina is scanned, the light beam traces a standard path and produces a pattern. This pattern is compared with the database for authentication.

Iris Scanning

Iris is a thin circular structure located in the front of a human eye. Iris determines the size and diameter of the pupils, which in turn determines the amount of light reaching the retina. Iris is unique to an individual. Iris scanners measure the unique patterns in the Iris.

Iris scanning involves using a camera to capture the images of the iris. Visible and infrared light is used to capture the images. High-resolution images of the Iris are taken to map the intricate structure. This image is then fed into Iris recognition software where the pattern of the iris is translated (image is converted into a code) and stored as an iris template.

Unlike Retinal scanning, Iris scanning uses a camera to take a picture of an iris and compares it with a database. Retinal scanning involves passing a light beam through the retina to capture retinal patterns. Hence, iris scanning can be done from a distance, whereas retinal scanning needs individuals to be present close to the light source. Further, Iris is located at the front of an eye, and retina is located at the back. Hence, Iris scanning is considered less invasive than retinal scanning.

Facial Authentication

Facial authentication is a technology to recognise faces based on the spatial geometry of distinguishing features. It is preferred over other biometric means because it is widely believed to be the least intrusive and fastest biometric technology.

There are different versions of facial authentication. For instance, Apple uses FaceID on iPhone X smartphones with the TrueDepth camera. This camera captures face data by projecting and analysing over 30,000 invisible dots to create a depth map of the face plus an infrared image. OnePlus has Face Unlock, which uses over "100 identifiers" such as distance between the eyes or the nose and upper lip.

Face authentication is as unique as fingerprints. Face authentication cannot be replaced by photograph of the user or by scanning a sleeping person's face. This is because face authentication considers liveliness as a factor for authentication, which is judged by attentiveness of the subject's eyes.

However, it is not foolproof. There have been cases when people with similar faces, especially twins have been able to unlock devices with face authentication.

Biometric Authentication and Biometric Identification

Authentication involves matching the submitted biometric feature with the already stored template. When it comes to identification, the aim of the biometric technology is to simply find a match within a database. For instance, law enforcement officials scan biometrics and compare them with the biometrics associated with wanted criminals.

In other words, the difference between biometric authentication and biometric identification can be learnt by asking the following questions:

Is a user requesting access to a secure physical or digital process? That is authentication. Is the person using the technology trying to discover something about a scanned individual? That is identification.

CAPTCHA

CAPTCHA stands for Completely Automated Public Turing Test to Tell Computers and Humans Apart. CAPTCHA is used to verify if the internet user is a real person or a bot. Bot is a software program used to perform certain simple and repetitive tasks on the internet at higher speeds than humans. Bots can visit websites, collect information such as email addresses, copy content from different websites, or explore vulnerabilities on the website to hack it.

If too many bots visit a website, it increases the load on the server. This may discourage the actual human users from exploring the website as the webpages may take a lot of time to load. Hence, many companies employ CAPTCHA to restrict bots from accessing their sites.

CAPTCHA uses specific traits of humans that cannot be possessed by machines to verify the identity of the user. For instance, an image of distorted letters may be displayed and visitors are required to type the letters in a specified space. Bots lack the skills of thinking abstractly, and cannot read the distorted images.

However, from a consumer's perspective, this verification adds an extra step to access a website. It can sometimes be annoying as well. To address this issue, certain websites use a new CAPTCHA called reCAPTCHA to make the verifying process easier. Instead of reading and typing a text, one needs to check a box. The reCAPTCHA tracks the movement of the mouse, looks at the visitor's IP address and cookie activity to verify whether the behaviour resembles a human or a bot.

4 AADHAAR (TARGETED DELIVERY OF FINANCIAL AND OTHER SUBSIDIES, BENEFITS AND SERVICES) ACT 2016

The Aadhaar Act was enacted in 2016 to make provisions for effective delivery of services by the Government to Indian residents. The act aims to reduce the leakages, duplication, and corruption in delivering subsidies and benefits to residents by the Government. Leakages occur when only a part of the intended benefits reach the desired social groups. Duplication occurs when a single individual poses as multiple persons and receives the same benefits multiple times.

Aadhar ensures targeted delivery to an individual by assigning a unique 12 digit identity number. Following are some of the provisions of the Aadhaar act:

1. An Indian resident is entitled to get an Aadhaar number by submitting the required information.
2. Fingerprints and Iris of the individual are scanned as part of biometric information.
3. An Aadhaar number is unique to an Individual. No two individuals can have the same Aadhaar number.
4. The act makes provisions for the establishment of Unique Identification Authority of India (UIDAI), which is responsible for the processes of enrollment and issue of Aadhaar, and thereafter authentication of Aadhar holders.

The act makes the following provisions to ensure the data privacy of an individual:

- The act mandates that the biometric information collected can be used only for generation of Aadhaar number and authentication purposes. It cannot be used for any other purposes.

- The identity information such as aadhaar number, demographic information (name, date of birth, etc), can be shared in accordance with the regulations made by UIDAI.
- Any entity that uses Aadhaar authentication by submitting the details to Central Identities Data Repository (CIDR) needs to use the details only for authentication purposes. Further, the entity needs to obtain the consent of an individual before collecting and using the Aadhaar information for authentication. The entity cannot disclose the Aadhaar information to a third party without obtaining prior consent of the Aadhaar holder.

The act was amended in 2019 to make provisions for offline verification of Aadhaar. Offline verification refers to the process of verifying the identity of the Aadhaar number holder without authentication. In other words, verification is done through offline modes and does not involve sending information to CIDR. The offline modes will be specified by UIDAI in the future.

Aadhaar Verdict 2018

The Supreme Court, in its judgment on the case of Justice Puttaswamy v Union of India, made the following observations with reference to the provisions of Aadhaar Act:

1. The court disallowed private entities to seek Aadhaar data. In other words, private entities cannot submit Aadhaar data mandatory for their customers. However, government schemes and subsidies for which payment is made out of the consolidated fund of India mandatorily require Aadhaar data to verify the identity of beneficiaries.
2. Aadhaar and PAN linkage is held as valid. This means that an individual needs to submit his Aadhar details to Income Tax authorities, and link it with his PAN. However, mobile numbers and bank accounts need not be linked with Aadhaar.
3. An individual may choose to share his Aadhaar details as identity proof with private entities.
4. Aadhaar metadata cannot be stored for more than six months. The 2016 act allowed the storage of metadata for five years. The court reduced this to 6 months. Metadata refers to data that can be used to obtain information about other data. For instance, metadata on transactions made at different locations can be used to trace the places at which the individual was present.

Practice Questions

1. Which of the following types of biometric authentication is required to be submitted while applying Aadhaar?

1. Face
2. Iris
3. Retina
4. Fingerprints

Select the correct answer using the codes given below:

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

2. With reference to data protection techniques, consider the following statements:

1. Anonymisation is a reversible process in which personal data of an individual is removed from the dataset.
2. Pseudonymisation is an irreversible process in which personal data is converted into a fictitious code.

Which of the statements given above is/ are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

3. With reference to data encryption, consider the following statements:

1. Symmetric data encryption has a single secret key for both encryption and decryption of data.
2. Asymmetric data encryption uses a public key for encryption and a private key for decryption.
3. Asymmetric encryption consumes less time and processing power compared to symmetric encryption.

Which of the statements given above is/ are correct?

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

4. Which of the following is the term used to represent the messages sent by a web server to a web browser when a user visits a website?

(a) Filter bubble
(b) Cookies
(c) Captcha
(d) Psychographics

5. With reference to biometric authentication, consider the following statements:

1. Retinal scanning technology is considered less intrusive than iris scanning.
2. During Iris scanning, a light beam is sent through the iris to identify the pattern of blood vessels.
3. In retinal scanning, a high resolution image of the retina is taken using a camera to compare it with the existing database.

Which of the statements given above is/ are **not** correct?

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

6. Which of the following can be used to manipulate an individual's behaviour online?

1. Data Profiling

2. Data localisation
3. Echo chamber

Select the correct answer using the code(s) given below:

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

7. Which of the following pair(s) is/are correctly matched?

Data protection technique	**Definition**
1. Data encryption	Personal data is hidden using a secret code
2. Data generalisation	Sensitive data is replaced with false details
3. Data profiling	Sensitive information is masked out

Select the correct answer using the code given below:

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

8. Consider the following statements:

1. In India, it is mandatory to link Aadhaar details with the Permanent Account Number (PAN) of an individual.
2. Unique Identification Authority of India (UIDAI) is a statutory body that issues and authenticates Aadhaar details of an individual.
3. Offline authentication can also be carried out using Aadhaar details.

Which of the statements given above is/are correct?

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

9. Consider the following statements:

1. Third party cookies are used to track the data of an individual across different websites.
2. Session cookies are temporary and expire as soon as the browser is closed.
3. Cookies are used to enhance the user experience while using the internet.

Which of the statements given above is/are correct?

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

10. According to the guidelines issued by the Reserve Bank of India, which of the following information should be stored by data processing companies only in India?

1. Payments and financial transactions made by Indian residents
2. Demographic information related to Indian residents
3. Information related to browsing habits of Indian residents

Select the correct answer using the code given below:

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

PERFECTING PAST PRELIMS

1. Consider the following statements: The Reserve Bank of India's recent directives relating to 'Storage of Payment System Data', popularly known as data diktat, command the payment system providers that **(2019)**

1. They shall ensure that entire data relating to payment systems operated by them are stored in a system only in India
2. They shall ensure that the systems are owned and operated by public sector enterprises
3. They shall submit the consolidated system audit report to the Comptroller and Auditor General of India by the end of the calendar year

Which of the statements given above is/ are correct?

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

2. Consider the following statements: **(2020)**

1. Aadhaar metadata cannot be stored for more than three months.
2. State cannot enter into any contract with private corporations for sharing Aadhar data.
3. Aadhaar is mandatory for obtaining insurance products.
4. Aadhar is mandatory for getting benefits funded out of the Consolidated fund of India.

Which of the statements given above is/ are correct?

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

ANSWER KEYS

Practice Questions

1. (c)	**2.** (d)	**3.** (a)	**4.** (b)	**5.** (d)
6. (b)	**7.** (a)	**8.** (d)	**9.** (d)	**10.** (a)

Perfecting Past Prelims

1. (a)	**2.** (b)

Solutions

Practice Questions

2. (d) Statement 1 is incorrect: Anonymisation is an irreversible process. The anonymised data cannot be traced back to the individual.

Statement 2 is incorrect: Pseudonymisation is a reversible process. The personal data is replaced with pseudonyms (artificial identifiers). This data can be re-converted to original data.

3. (a) Statement 3 is incorrect: Symmetric encryption consumes less time and processing power.

5. (d) Retinal scanning is considered more intrusive as it involves projecting a light beam from very close proximity on the retina, located at the back of an eye. In Iris scanning, a camera is used to take an image of the iris.

6. (b) Data localisation refers to storing data related to a country's residents within the country.

7. (a) Pair 2 is incorrectly matched: Data generalisation is a process in which specific data values are replaced with a range of data. Sensitive data is replaced with false details in a process called pseudonymisation.

Pair 3 is incorrectly matched: Data profiling refers to the process of using data to analyse and predict behaviour patterns of individuals.

Perfecting Past Prelims

2. (b) Statement 1 is incorrect: According to the Supreme Court verdict in Justice Puttaswamy v Union of India, Aadhaar metadata cannot be stored for more than 6 months.

Statement 3 is incorrect: Aadhar is not mandatory for obtaining insurance products.