Biotechnology in India

[UPSC Notes]

What is Biotechnology?

Genetic engineering was developed in 1970, research in biotechnology (and other interconnected fields such as biology, medicine, etc.) led to the rapid evolution of biotechnology as it increased the possibility of altering the genetic material (DNA) of various organisms'.

Biotechnology is responsible for manufacturing any pharmaceutical drug product for the industries and biologicals using genetically modified plants, animals, microbes, and fungi. The uses of biotechnology in enormous, and its mechanism are utilized in the following fields:

- Diagnostics
- Bioremediation
- Genetically Modified Plants For Agriculture
- Therapeutics
- Processed Food
- Waste Treatment
- Energy Production

Department of Biotechnology (DBT) in India

Department of Biotechnology, generally abbreviated as DBT India, mainly focuses on developing human resources, creating appropriate infrastructure, research and development, and a regulatory framework.

There is a continued effort on many public aspects like health care, food and agriculture, energy, and environmental security. The Department of Biotechnology comes under the Ministry of Science and Technology and handles most of the programs in the Biotechnology sector in India. Its objectives are:

- To assist in research, infrastructure, generation of human resources, increasing the popularity of biotechnology, and advancement of industries.
- Implementing biosafety policies for GMO or genetically modified organisms, recombinant DNA products, and biotechnology-based programs for the benefit of society.
- To establish an information network for the Bioinformatics mission of India in the scientific community, nationally and internationally.

Currently, the Society of Biotechnology of India (SBPI) facilitated transformation changes and practices toward research in Biotechnology. This was done so that the outcome yields better products and leads to economic gain.

Genetic Engineering Appraisal Committee (GEAC)

This committee works under the Ministry of Environment, Forest and Climate Change (MoEF&CC). The chairman of GEAC is the special or additional Secretary and is co-chairman is a representative from the Department of Biotechnology (DBT).

It has the following responsibilities in Biotechnology:

- It is accountable for the assessment of activities concerning the wide use of dangerous microorganisms, industrial production, and recombinants utilized in research.
- It is responsible to implement proposals relating to the release of GMO or genetically modified organisms and their by-products into the surroundings.

Branches of Biotechnology

A series of derived terms have been pointed out to identify several branches of biotechnology.

- **Bioinformatics**: It is an interdisciplinary field that addresses biological problems using computational techniques and makes rapid organization and analysis of biological data possible.
- **Blue Biotechnology:** It is the term that has been used to describe the marine and aquatic applications of biotechnology, but its use is relatively rare.
- **Green Biotechnology:** Biotechnology in agriculture UPSC topic is widely asked in prelims exams. Biotechnology in agriculture has proved to be revolutionary and researchers are still in it its process. e.g., BT cotton (micropropagation).
- **Red Biotechnology:** Red Biotechnology is applied in the medical process. Example,
    1. The development of organisms capable of producing antibiotics.
    2. Genetic engineering for genetic manipulation.
- **White Biotechnology:** It is also known as industrial biotechnology or biotechnology applied to industrial processes.

Tools in Biotechnology

- **Genetic Engineering**: It refers to the direct human manipulation by which a foreign gene is inserted into the DNA of an unrelated organism. Genetic engineering techniques are used in many fields, that includes research, biotechnology, and medicine.
- **Plant Tissue Culture**: It is a technique of growing tissues or cells of a multicellular organism in an artificial environment. It is beneficial in clonal propagation on a large scale, especially ornamental and horticultural plants, for obtaining disease-free plant material and producing biologically active compounds for the pharmaceutical industry.
- **Cell cryopreservation** is a process where cells and whole tissues are preserved by cooling to a low sub-zero temperature, such as minus 196 degrees Celsius, which is the boiling point of liquid nitrogen. At this low temperature, any biological activity, including the biochemical reaction that could lead to cell death, is effectively stopped.
- **Cloning**- The world clone is derived from the Greek word ‘klon’, which means twig (part of a plant used for reproduction). clone is exact replicas of plants or animals replicated sexually it means making an identical copy physically as well as genetically. Dolly was the mammal to have been successfully cloned from an

adult cell and was born in 1996 in Roslin Institute in Scotland and lived there until death 7 years later.

- **Stem cells-** They differ from other kinds of cells found in the body by having two important characteristics that distinguish them from other types of cells. What are stem cells are cells that renew themselves for a long period through cell division, and stem cells can be induced to become cells with a special function, such as beating cells of the heart muscle.

  Insulin cell production in the pancreas can be increased under certain psychological and experimental conditions. There are two kinds of stem cells in animals and human beings.

- Embryonic stem cells
- Adult Stem Cells

- **Microbial Biotechnology:** Microbes and microorganisms are organisms that are too small to be seen by the naked eye. They include bacteria, fungi, protozoa, microalgae, viruses, etc. It lives in soil, water, food, and animal intestines.

  It encompasses the use of microorganisms in the process of manufacture of food or other industrial products—cheese, chocolate, butter, pickles, sauce, and alcohol—all produced by the industrial microbial process.

- **Monoclonal Antibodies:** These are the techniques where pure antibiotics are produced. Technology allows for the production of a large number of pure antibiotics, which have two useful properties:
  1. They are extremely specific and bind to and attack one particular antigen.
  2. Some antibodies once activated by the occurrence of the disease continue to confer resistance against the diseases.

Application of Biotechnology in Medicine

In the scope of healthcare, laboratory methods of genetic recombination have made a tremendous influence. This process of biotechnology facilitates large products of secure and more efficacious drugs. Specialized medicines made up of recombinant proteins are incapable of generating unwanted immunological reactions.

Genetically Engineered Insulin in Biotechnology

The main role of insulin is to manage the starting phase of diabetes in adults at regular intervals. Insulin comprises two polypeptide chains: A and B, interlinked by disulfide bonds.

In mammals, insulin is synthesized as a hormone precursor, for example, in humans. This prohormone [having an extra stretch of C-peptide] finally becomes a completely active and

mature hormone. The C-peptide is removed during the insulin maturation process. Collecting insulin into a mature form was the main complication in creating insulin using rDNA techniques.

Biotechnology Uses in Gene Therapy

Gene therapy is a correctional therapy to cure a person born with a congenital disease. This technology includes a bunch of strategies wherein gene correction occurs whenever a defect is analyzed in an embryo. Any genetic defect gets modified after a healthy gene is delivered into the embryo, and it takes over the part of the non-functional gene by compensating it.

Curing Deficiency of Adenosine Deaminase (ADA) with Biotechnology

ADA stands for Adenosine deaminase, an enzyme that enables the immune system to work properly. This deficiency occurs because of the gene omission that codes for the adenosine deaminase enzyme. With gene therapy, patients' lymphocytes are extracted and grown in a laboratory. An active ADA cDNA (complementary DNA) is inserted utilising a retroviral vector that delivers genetic material into the lymphocytes and returns to the patient's body.

However, these genetically engineered white blood cells or lymphocytes must be periodically infused into the patient's body. To permanently cure this defect, the gene-producing Adenosine Deaminase enzyme must be isolated from the bone marrow cells and introduced into the embryo cells at the early stages of development.

Biotechnology Application in Molecular Diagnosis

Early identification and diagnosis of a disease's pathophysiology are important for effective treatment. It is impossible to detect any disorder using traditional urine and serum analysis methods. Processes that help in the early diagnosis of diseases are:

- PCR - Polymerase Chain Reaction
- ELISA - Enzyme-Linked Immuno-sorbent Assay
- DNA Recombinant technology

Bacteria, viruses, or any other pathogen's presence is only seen when a symptom of a disease is sensed during the time its concentration is very high in the body. A very less concentration of any pathogen can be easily seen by amplification (creating multiple copies) of their nucleic acid. Their copies are generated using the polymerase chain reaction method, abbreviated as PCR.

HIV Diagnosis In Biotechnology

PCR technique is used to diagnose HIV AIDS in patients. The method can detect mutations/changes in the genes of cancer patients. PCR is an effective procedure that can detect various genetic disorders.

How does PCR work in Biotechnology?

- sDNA or sRNA ("s" stands for single-stranded) is tagged with a probe (a molecule which is radioactive in nature and is able to scatter excess energy by spontaneously ejecting radiation in the form of rays).

- It is allowed to merge with its complementary DNA, and the process is detected by using a photographic method that detects radioactive materials, known as autoradiography.
- The clone bearing the transformed gene is not detectable on the film because the probe will not have a complementary bond with the mutated gene.

ELISA works on the mechanism of interaction between antigen and the antibody. Infection by a pathogen is detected either by the existence of antigens (glycoproteins, proteins, etc.) or when the number of antibodies produced against the microbe is seen.

CRISPR technology

CRISPR is another strong tool that helps in editing genomes. The technology lets researchers modify the sequences of the DNA and alter the gene's function. Bacteria contain a naturally available editing system of the genome from which CRISPR-Cas9 is adapted.

The bacteria capture fragments of DNA from intruding viruses and create CRISPR arrays or DNA segments due to which bacteria recognize the viruses. The bacteria make RNA molecules if viruses attack again and target their DNA using the rays of CRISPR. The technology is still being researched on various diseases where DNA changes in one particular gene such as hemophilia, sickle cell disease, and cystic fibrosis.

Application of Biotechnology in Producing Transgenic Animals

Transgenic animals have altered DNA to retain and represent an additional (alien) gene. This application of Biotechnology produces transgenic sheep, rabbits, pigs, fish, cows, and rats. However, transgenic mice have more utility and constitute 95% of transgenic animals.

Physiology and Normal development

In Biotechnology, transgenic animals are designed to study how genes are controlled and how they impact the body's normal functions and growth. For instance, they help study growth factors like insulin, which are complex elements for growth. The biological role and effects of the factor in the transgenic animal's body are obtained by introducing other species' genes that alter the formation.

Study of disease

The creation of transgenic animals improves our knowledge of the contribution of genes in any disease development. These animals act as models to investigate unexplored treatments for human diseases. Many deadly diseases like rheumatoid arthritis, Alzheimer's, cancer, and cystic fibrosis now utilize transgenic models for their study and treatment.

Biological products

Biological products are a part of medicines that treat certain human diseases and are often expensive to create. Rosie, is known to be the first developed transgenic cow in 1997, that

produced protein-supplemented milk containing human alpha-lactalbumin. It was known to be nutritionally a more balanced dose for human babies.

The introduction of the portion of DNA in the transgenic animals can be performed to yield beneficial biological products. These DNA codes for a special product such as human protein (α-1-antitrypsin), which treats Emphysema. A lot of trials are being performed to be able to treat cystic fibrosis and phenylketonuria (PKU).

Vaccine safety

As mice comprise the majority of transgenic animals, they are being created to be used in testing the safeness and efficacy of any newly launched vaccines before being applied to humans. Earlier, mice were useful to test the polio vaccine safety and will replace the use of monkeys if they are found to be more reliable in testing the vaccine batches.

Chemical safety testing

The use of transgenic animals in toxicity/safety testing tests the toxicity of any drug. They carry genes that make them more sensitive to harmful substances. These animals are exposed to toxicity, and the results are analyzed in a very short time.

Applications of Biotechnology in Agriculture

Biotechnology In Agriculture UPSC has a very significant role in this field. Biotechnology was able to beat the conventional farming methods soon after genetically modified crops came into the limelight. Understanding genetics helped farmers in the following ways:

- They were able to obtain maximum yields from farming ground
- Genetically modified crops reduced the use of fertilizers and chemicals
- The environment became less harmful.

The technology created Genetically Modified Organisms (GMO), Genetically modified biopesticides, and Pest resistant plants, which have contributed to improving the quality of the plants.

Genetically Modified Organisms (GMO) in Biotechnology

GMO or genetically modified organisms comprise those fungi, plants, bacteria, and animals whose genes have been transformed. GM plants have been beneficial in the following ways:

- Crops became more resistant to environmental stresses (salt, cold, drought, heat).
- Pest-resistant crops lessened the dependence on synthetic pesticides, which impact the environment.
- It resulted in reducing losses due to post-harvest.
- The efficient usage of minerals by plants was increased drastically (It controlled early exhaustion of soil fertility).
- The nutritional quality of food was enhanced as there was the introduction of golden rice, i.e., Vitamin 'A' enriched rice.

Genetically modified biopesticide in Biotechnology

In Biotechnology, Genetically modified biopesticides have been quite useful in creating eco-friendly pesticides. One of the examples is Bt (Bacillus Thuringiensis) toxin produced by a bacterium. Some examples of GM biopesticides are Bt cotton, Bt corn, rice, tomato, potato, Soyabean, etc.

- The copies of the Bt toxin gene from the bacteria were made and expressed in plants. This gene offers the plant resistance to insects without the necessity of insecticides.
- Bacillus Thuringiensis strains were able to secrete proteins that kill specific insects such as armyworms, beetles, tobacco budworms, flies, and mosquitoes).
- B. Thuringiensis can form crystals of proteins during a special growth phase, which contains a contaminated protein that can kill insects.

Pest-resistant plants in Biotechnology

Pest-resistant plants are produced by a novel strategy based on the process of RNA interference (RNAi). RNAi is a cellular defence system in all eukaryotic cells [containing a nucleus within a nuclear envelope]. This method silences a specific mRNA due to a complementary dsRNA molecule that attaches to and prevents the making of mRNA proteins (silencing).

Several nematodes parasitize a wide variety of plants and animals, including human beings. A nematode Meloidogyne incognita contaminates the roots of tobacco plants and causes a considerable decrease in yield.

Recent Advancement In Biotechnology

- **Miniature eyes:**

  Hyderabad researchers have successfully grown miniature eye-like organs that resembled the developing eyes of early-stage embryos, so they are produced using induced pluripotent stem cells, which are types of stem cells that can be generated directly from adult skin cells by genetically manipulating human skin cells via epigenetic reprogramming.

  Human Antibodies In Laboratory- For the first time, scientists have produced human antibodies in the laboratory. This will help in developing new vaccines for a wide range of diseases.

- **Biofilms (A Community Of Bacteria):** These are communities of microorganisms that are attached to each other and to surfaces; they act as barriers to antibodies. It happens during harsh conditions like high temperatures, where the bacteria come together and form a biofilm for production.
- **Flink (Functional Ink) -** Functional living ink is a new printing material developed by scientists in Switzerland. It contains different bacteria as ink, so it is possible to print or develop objects with biochemical properties (3D printing). Different

species of bacteria are used in different concentrations, so it allows printing using different inks and produces objects with several properties.

- **Plants That Glow:** Scientists have successfully found a way to embed specialized nanoparticles into the leaves of plants. The plant will glow, giving dim light illuminating the workplace, indoor lightning, trees as self-covering street lights, etc.

- Phantom-3d (Model Of Human Finger Printing) - Anil Jain and a team of computer scientists at Michigan State University led by Anil Jain built the first 3D model of the fingerprint. It is a method that takes the 2D images of fingerprints and maps them into the 3D finger surfaces. 3D finger surfaces make up a human fingerprint after completing all ridges and valleys and making use of a 3D printer. It forms a fingerprint, Phantom. It is used to create a 3D heart and kidney because the dimensions are known.

- Heat Shock Protein - Scientists have discovered the potential silencing mechanism has-90. In normal circumstances, HSP 90 keeps genetic mutations under check. In stressful situations, reservoirs of HSP 90 get depleted, allowing genetic mutations to manifest as trade. This allows the organism to quickly adapt to changes in the environment.