General Science

Short Answers

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Biotechnology

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CHAPTER 2: BIOTECHNOLOGY

CONTENTS

2.1 INTRODUCTION TO BIOTECHNOLOGY

Although the use of Biotechnology has been documented right since very early times in a very rudimentary form, without modifications and innovations, it could be said that modern biotechnology was born in the year 1971 when **Paul Berg's experiments in gene splicing had early success. In 1972** a new technology was advanced by Herbert W. Boyer, University of California, San Francisco (UCSF), in collaboration with Cohen of Stanford University, which involved transferring genetic material into a bacterium, such that the imported material would be reproduced. **Ananda Chakrabarty**, an American-Indian scientist, had **modified a bacteria (of the genus Pseudomonas) capable of breaking down crude oil, which he proposed to use in treating oil spills**. This work did not involve genetic manipulation; it was rather based on the transfer of entire organelles between strains of the Pseudomonas bacterium. Biotechnology deals with techniques of using **living organisms or enzymes from organisms** to produce products and processes useful to humans.

E.g.: Making curd or bread, are all microbe-mediated processes that could also be thought of as a form of biotechnology.

Growth and maturity of modern biotechnological processes using genetically modified organisms was made possible **only when man learnt to alter the chemistry of DNA and construct recombinant DNA. This key process is called recombinant DNA technology or genetic engineering.**

Note:- DNA alterations involve using restriction endonucleases, DNA ligase, viral vectors or appropriated plasmids to isolate and transport the foreign DNA into host organisms. It results in expression of the foreign gene, and purification of the gene product. Whereas a Large scale production involves use of bioreactors (Bioreactor is an apparatus in which a biological reaction or process is carried out, especially on an industrial scale).

Today Biotechnology has a wide range of applications and usage in several fields like Molecular biology, Cell culture, Genetic modification of higher levels in agricultural and scientific development etc.

2.2 DEFINITION OF BIOTECHNOLOGY

The wide concept of "biotech" or "biotechnology" covers a range of procedures and techniques for modifications of living (biological) organisms according to human purposes, needs, motives and requirements as per times, and dates back to domesticating animals,

cultivating plants, and "**improvements" to these through breeding programs that employ artificial selection and hybridization**. **Modern usage also includes Genetic engineering techniques as well as cell and tissue culture technologies, among many other applications.** Broadly, Biotechnology can be defined as "**use of biological systems of organisms or the use of the living organisms themselves, to make technological advances in order to adapt those technologies to various different fields, ranging from agricultural practice to the medical sector.**

2.3 PRINCIPLES OF BIOTECHNOLOGY

The two crucial technologies, which are the core of biotechnological principles are: genetic engineering and chemical engineering.

i. Genetic Engineering

The principle of genetic engineering is to modify the existing organisms by changing the genetic material in them. It mainly includes recombinant DNA technology.

Recombinant DNA Technology is a technique which changes the phenotype of an organism (host) when a genetically altered vector (Genetically modified vectors offer complementary new approaches to integrate with the best existing methods) is introduced and integrated into the genome of the organism. Inserting the desired gene into the genome of the host is not as easy as it sounds. It involves the selection of the desired gene for administration into the host, followed by a selection of the perfect vector with which the gene has to be integrated and recombinant DNA formed. This recombinant DNA then has to be introduced into the host. And at last, it has to be maintained in the host and carried forward to the offspring.

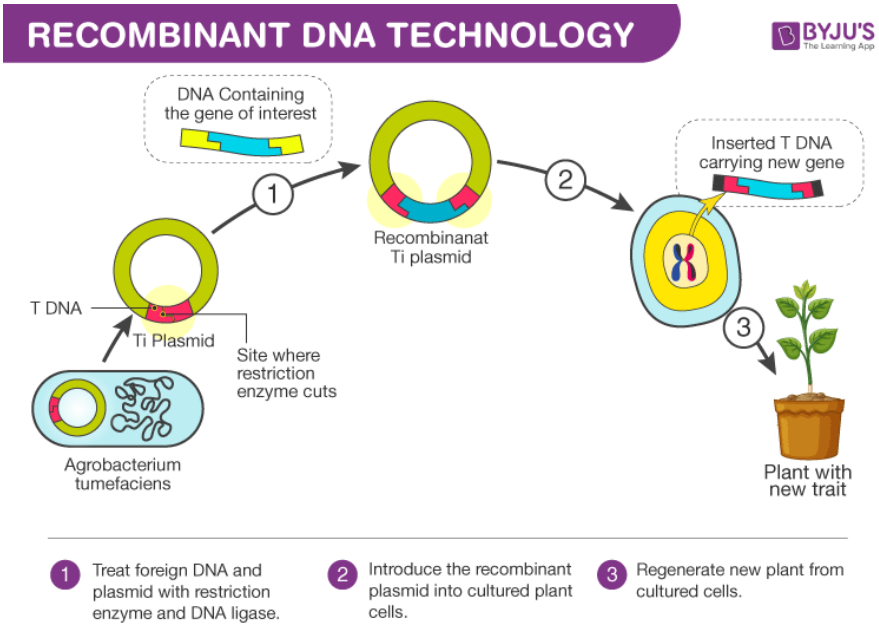


Fig 1.1:Recombinant DNA technology

The genetic engineering or the so-called Recombinant DNA Technology requires certain tools like restriction enzymes, and vectors to carry out the entire process.

ii. Process

- **The restriction enzymes** are a category of nucleases which help make a cut in the DNA at the respective positions.
- The DNA is ligated with the help of ligases before inserting it into the host organism
- The DNA-vector combination is known as the Recombinant DNA which is finally transferred into the host.
- These vectors can independently replicate within the bacterial cells and are, hence, used for the transformation of the recombinant DNA within the host organism.
- This recombinant DNA, also known as the foreign DNA, gets multiplied within the host.
- It is then provided with optimum conditions to induce the expression of the target protein. This protein is known as the recombinant protein.

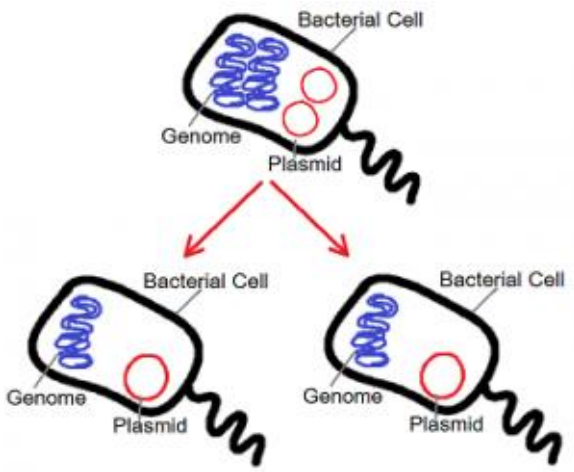


Fig:1.2 Recombinant DNA technology

iii. Three-Parent Baby Technique

Under the three-parent baby technique, human offspring are produced from the genetic material of one man and two women through the use of assisted reproductive technologies specifically mitochondrial manipulation technologies and in-vitro fertilization. In general reproductive technology used to produce three-parent babies focuses on replacing or otherwise reducing the effects of mutations that occur in the DNA of cellular organelles known as mitochondria which are found inside the cytoplasm. The various approaches could

help women to overcome infertility and could prevent the transmission to their offspring of potentially debilitating and harmful mitochondrial diseases.

The first three-parent babies were born in the 1990s and early 2000s products of a novel IVF based technique known as a plasmic transfer. The success of the technique was seen as miraculous but its use was controversial it prompted scientist to develop improve technology and cause regulatory agencies to restrict the use of three-parent IVF. Much was unknown about the safety of various three-parent IVF techniques and their use to general human babies raised ethical and social concerns, among them, the primary was the possible impact on health and heredity.

iv. Mitochondrial Manipulation Technologies used in Three parent Baby

Earlier Ooplasmic transfer technology was used for mitochondrial manipulation but due to its side effects, other techniques have evolved, over the years two of which are very significant.

v. Maternal Spindle Transfer

In maternal spindle transfer, the nucleus is removed from a donor egg, leaving behind the cytoplasm. The nucleus from the mother's egg cell is then inserted into the donor egg. The egg is fertilized with the father's sperm and then transferred to the mother's uterus for normal gestation, similar to other IVF procedures.

vi. Transfer

In pronuclear transfer, the mother's egg is first fertilized with the father's sperm, producing a zygote. The pronuclei of the egg and sperm are then removed from the zygote and inserted into a donor egg that has been fertilized and has had its nucleus removed (a pronucleus is the nucleus of the egg or sperm at the stage of fertilization before nuclear fusion). The zygote derived from the donor egg is then implanted into the mother's uterus**.** It is generally seen that as zygote possess a nucleus that houses a genome comprising nuclear DNA from both the father and the mother mitochondria that is how the distinct Junoon which is solely composed of mitochondria DNA from the mother inherited mitochondrial DNA accounts for only a very small percentage of total DNA in the cell get the ability of an egg to be fertilized successfully is thought to be associated with the health of a woman's mitochondria particularly DNA. Operations have been identified as between reduced mitochondria tree and quantity and infertility as well as between mutations and fertilization rates.

Mutations in mitochondrial DNA are a cause of mitochondrial disease which is a heterogeneous group of diseases that can lead to premature death, sometimes in infancy or childhood. Most mitochondrial diseases lack specific treatments, and women who carry the

causative mutations are at high risk of transmitting the diseases to their offspring. Risk of transmission is greatest for women with high heteroplasmy women whose total mtDNA content in affected cells or tissues is made up of between 60 and 90 percent mutated mtDNA, the threshold at which mitochondrial disease becomes apparent clinically. However, even women with low heteroplasmy and who are therefore asymptomatic are at risk of passing on mitochondrial disease to their offspring. In such women, heteroplasmy levels can be increased by phenomena such as selective replication of mtDNA and mitochondrial bottleneck, in which only a select number of mtDNA molecules are transferred to eggs at the time of egg maturation.

Hence, both maternal spindle transfer and pronuclear transfer attempt to minimize heteroplasmy by replacing the mother's mitochondria with healthy donor mitochondria. Ooplasmic transfer, on the other hand, may contribute to heteroplasmy, thereby possibly diluting the effects of mutations in maternal mtDNA and enabling embryo survival. The precise mechanisms by which any of the three techniques could potentially treat infertility or prevent inherited mitochondrial disease are not fully known.

2.4 MODERN BIOTECHNOLOGY

Biotechnology, through genetic engineering, works directly with the genetic material of a cell. If we examined a cell under a high-powered microscope, we would see long, thread-like structures called chromosomes. These chromosomes, composed of DNA (deoxyribonucleic acid), are organized into sections called genes. Genes control the production of particular proteins, and proteins, in turn, determine the characteristics of an organism. In some cases, a gene may govern one particular trait, such as an organism's resistance to disease, while in other cases, characteristics may be determined by many genes. It was the understanding of DNA that paved the way for genetic engineering. The knowledge gained has allowed researchers to transfer genes between the cells of different organisms.

Cut and paste method

In this method, the actual transfer of a gene is carried out in a complex "cut and paste" procedure. In the cut and paste method, Specialized enzymes are used to "cut" or remove a specific gene from one organism's DNA, and then to "paste" or slice that gene back into the DNA of another organism.

The gene can be inserted into another organism through a variety of techniques, depending upon the characteristics and properties of the recipient organism, or whether the organism is an animal, bacterium or a plant. Some of the genetic engineering techniques used to modify organisms are:

ANIMALS	PLANTS	BACTERIA
A technique called **micro-injection** is the method often used to produce genetically engineered or transgenic animals. Through this technique, a very fine needle is used to inject a solution of DNA molecules containing genes that carry desired characteristics (such as disease resistance) into animal cells, usually at the embryo stage. The genes are incorporated into the animal cells genetic material, and the cells begin to express the characteristic determined by the new gene. Applying this micro-injection technique could have potential benefits for agriculture as well.	Plant cells have tough outer walls, making the delivery of genes into the plant cells a little more challenging than is the case for bacteria. There are two main techniques by which this process is carried out. The first of these involves the use of a modified species of a bacterium called Agrobacterium. In nature, the Agrobacterium invades a plant, then infects it with a segment of its own DNA that "codes" for the development of crown gall disease. This DNA is incorporated into the plant's DNA, and the plant becomes diseased with crown gall. When using Agrobacterium to modify plants genetically, these disease-causing parts of the Agrobacterium's DNA are removed. They are replaced with genes that carry desired characteristics (such as improved nutritional value)	In certain bacteria, small naturally occurring circular segments of DNA called plasmids are found, which can be used for genetic engineering. Plasmid DNA can be taken outside of the bacterial cell, modified with the addition of a new gene, and placed back into the cell. With the new gene, the bacterial cell can now manufacture the product of this gene as its own. Because bacteria reproduce very rapidly, large volumes of bacteria containing the modified plasmid can be used to produce commercially significant quantities of a gene product, such as a food additive or an animal vaccine, in short periods of time.

	by the "cut and paste" procedure. The Agrobacterium can then be introduced to plant cell material, where it is allowed to invade plant cells and introduce the new gene with the desired characteristics. The full plants grown from these plant cells express the characteristic determined by the new gene. Agrobacterium, therefore, is a convenient delivery system by which new characteristics can be passed on to plants.	

Particle Gun Method

The second technique used to deliver genetically engineered DNA into plants is called the DNA "particle gun" method. Tiny metal particles coated with genes with desired characteristics, such as improved nutritional value, are put into a particle gun and fired directly into plant cells. These genes are incorporated into the plant cell's DNA, and the cells are then grown into full plants. The new characteristic is thereafter present in the whole plant.

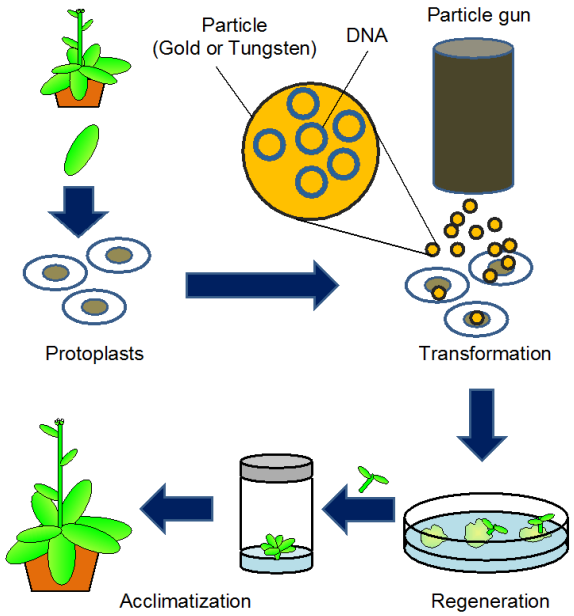


Fig 1.3: Particle gun Method

Plasmid Method

This method is the most commonly used in genetic engineering. This method uses small circular pieces of a DNA molecule called plasmids. This method is mainly used for altering microorganisms such as bacteria.

1) The plasmid is inserted into a container containing restriction enzymes. Restriction enzymes cut up the plasmids into small pieces.

2) Using the restriction enzymes, these cut pieces of plasmids are inserted into the bacteria and due to which sticky ends are produced. A sticky end refers to how the restriction enzyme cuts the DNA. If the cut was straight, then it is a blunt end, but if it is a staircase then it's sticky.

3) The sticky ends on the DNA from the plasmids combine with the sticky ends on the DNA inside the bacteria to form a ring of DNA. Other enzymes are added to make those ringed DNA molecules more stable. After they stabilize, they are put in safety to use for further processes.

4) A culture of live bacteria is then prepared with the newly formed plasmids and are placed together. These plasmids will then enter into the bacterial cell, and start expressing itself. During the expression, the plasmid will synthesize new proteins or antibiotic resistance genes. These new genes will help distinguish the plasmid bacteria from the non-plasmid bacteria.

Vector Method

A vector in molecular biology means a molecule of DNA, which serves as a carrier of genetic information into the cells. It is used especially in molecular genetics. Generally, it is consisting of inserted DNA sequence and larger DNA sequence which serves as a supporting structure. The most common vectors are plasmids, viruses, and artificial chromosomes.

Vectors are used especially to transfer genetic information into the cells to replicate and express the selected part of DNA. The whole process is induced by a promoter which is also contained in vector DNA. Inserting vectors into cells is called due to the target cell: transformation (for bacterial cells), transfection (for eukaryote), transduction (for viruses).

The vector method uses techniques similar to the plasmid method. This method uses vectors, which are small carrier molecules, which are normally viruses. Viruses are made of a protein capsule and have their DNA inside, and they attach onto a cell then inserts its DNA or RNA into the host cell, then it detaches itself. The DNA, now inside the host cell, will start replicating itself by using the genetic information of the host cell, which means the gene that was inserted will now be part of the host cell. The vector method is better than the plasmid method because the plasmid method offers genetic variation. After all, the newly formed plasmids are made with random pieces of DNA, while the vector method uses a specific gene to get a specific result. This will make the host give the desired features.

1) The strand of DNA is put into a container with specific restriction enzymes to separate a specific gene. Once the restriction enzyme cuts the gene of interest, that gene is then isolated from the rest and is ready to be inserted into a vector.

2) This gene is now inserted into a vector, in this case, it's a virus, and once the virus has accepted the gene of interest, it becomes a recombinant molecule. A recombinant molecule is just a vector with recombinant DNA attached.

3) The vector is now placed with the host cell, where it transfers the DNA to the cell. Once inside the cell, the DNA starts to replicate, the scientist then stops the vector's DNA from replicating and only allows the gene of interest to replicate.

4) The gene is now inside the host cells' DNA, and now the cell will have this gene.

Gel Electrophoresis

It is a technique that is used to directly see DNA fragments. Like, researchers can analyze the results of a PCR reaction by examination of the DNA fragments it produces on a gel. Gel electrophoresis leads to the separation of DNA fragments based on their size, and the fragments are stained with a dye so that researchers can see them.

2.5 APPLICATIONS OF BIOTECHNOLOGY

Biotechnology is an emerging field of research as it has the potential to solve many biological problems which have not been solved until now with the conventional techniques. Biotechnology extends its applications over a broad spectrum which includes medicines, agriculture, transgenics, genetic engineering, etc. Here we will discuss biotechnology in agriculture.

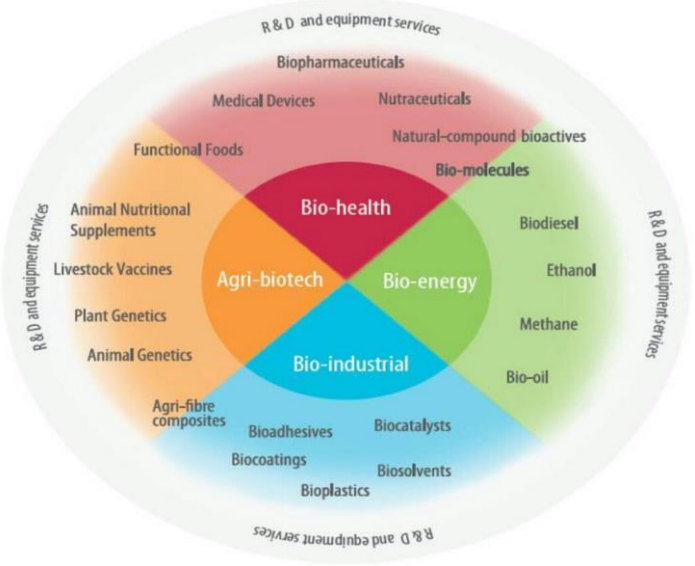


Fig:1.4 Applications of Biotechnology

i. TYPES OF BIOTECHNOLOGY

RED(MEDICINAL) BIOTECHNOLOGY	Medical biotechnology is the use of living cells and other cell materials for the purpose of bettering the health of humans. **E.g.:- Vaccine**
GREEN(AGRICULTURAL) BIOTECHNOLOGY	Agricultural biotechnology focuses on developing genetically modified plants for the purpose of increasing crop yields or introducing characteristics to those plants that provide them with an advantage.

	E.g.:- Selective plant and animal breeding
WHITE (INDUSTRIAL) BIOTECHNOLOGY	Creation of new and innovative materials, cellular structures etc
BLUE (ENVIRONMENTAL) BIOTECHNOLOGY(Marine, Aquatic, Plant and Animal etc)	Use of natural resources or biological modification techniques for lessening the impacts on environment **E.g:- biofuels, Ocean or marine engineering**
GOLD(NANO-BIOTECHNOLOGY)	It is the intersection of Nanotechnology and biotechnology, and this discipline helps to indicate the merger of biological research with various fields of nanotechnology
GREY (FORENSIC) BIOTECHNOLOGY	Forensic analysis of biological evidence using biotechnology methods is increasingly important in criminal investigations**.** **E.g.:- Analysis of proteins in the blood (serology), other body fluids and body tissues are some of the tradi-tional methods in forensic analysis.**

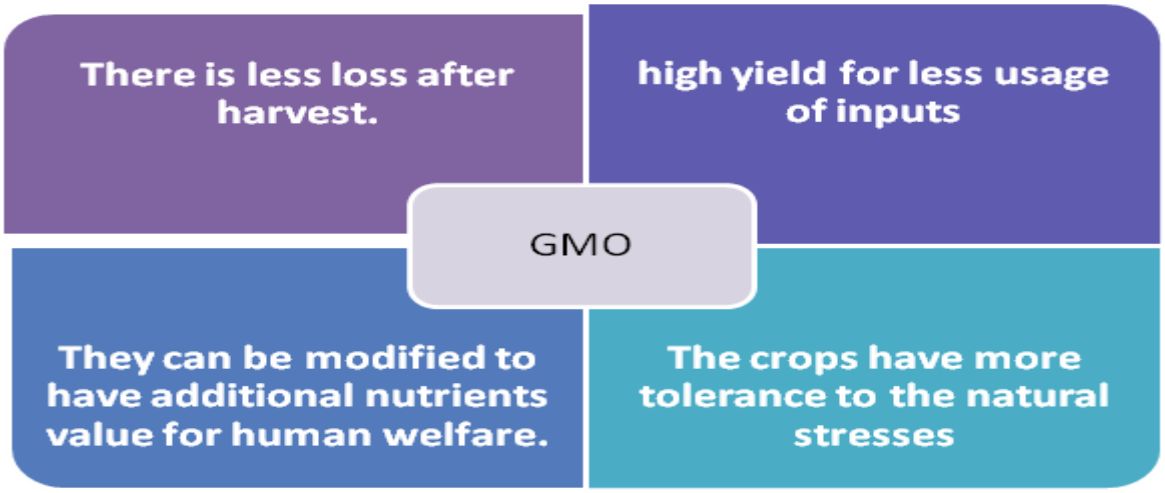
ii. AGRICULTURE AND BIOTECHNOLOGY

The large increase in the size of a population has led to a greater demand for basic requirements, including food, shelter, clothing, etc. Another impact of population on crops production is the exploitation of the land. Thus cultivation has been limited to a small area. In order to meet the demands with limited resources, we need to apply a great effort. Biotechnology in agriculture has changed the face of this condition. It is widely employed in different fields, and agriculture is one among them. Researchers have suggested different options for increasing food production. Genetically engineered crop-based agriculture is an option, others being agrochemical based agriculture and organic agriculture. **The Green revolution** was an initiation for increasing food production, but it couldn't meet the growing

demands. Later an idea was put forward for improvement of crop variety. There was also increasing use of agrochemicals. However, the increasing use of chemicals for these improved crop varieties seemed to be unfeasible for farmers. In addition, the environmental issues related to them also reduced their use.

2.6 GENETICALLY MODIFIED CROPS (GMO)

Genetically modified crops (GMO) a result of the alteration in the genetic makeup of the crops, are the latest advancement in the agricultural field.This modification leads to a number of advantages in the crops which include:-



One of the most common examples is that of Bt Cotton. Bt stands for Bacillus thuringiensis which, when introduced in plants develop resistance against pests like bollworms and corn borer. Thus, genetically modified crops help in optimizing the complete process of agriculture. Advancement of biotechnology in agriculture resulted in a variety of GMO, which include pest-resistant plants, disease-resistant plants, etc.

i. Some examples of Agriculture Biotechnology

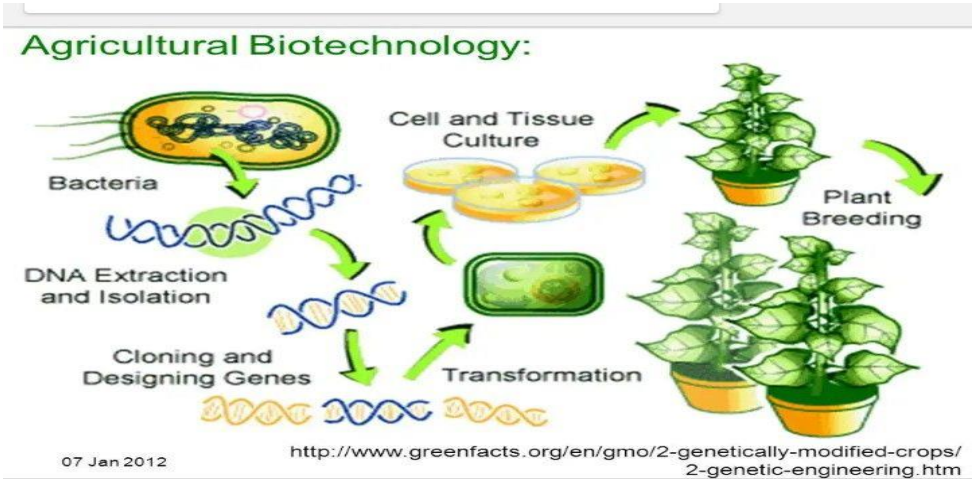


Fig:1.5 Agriculture Biotechnology

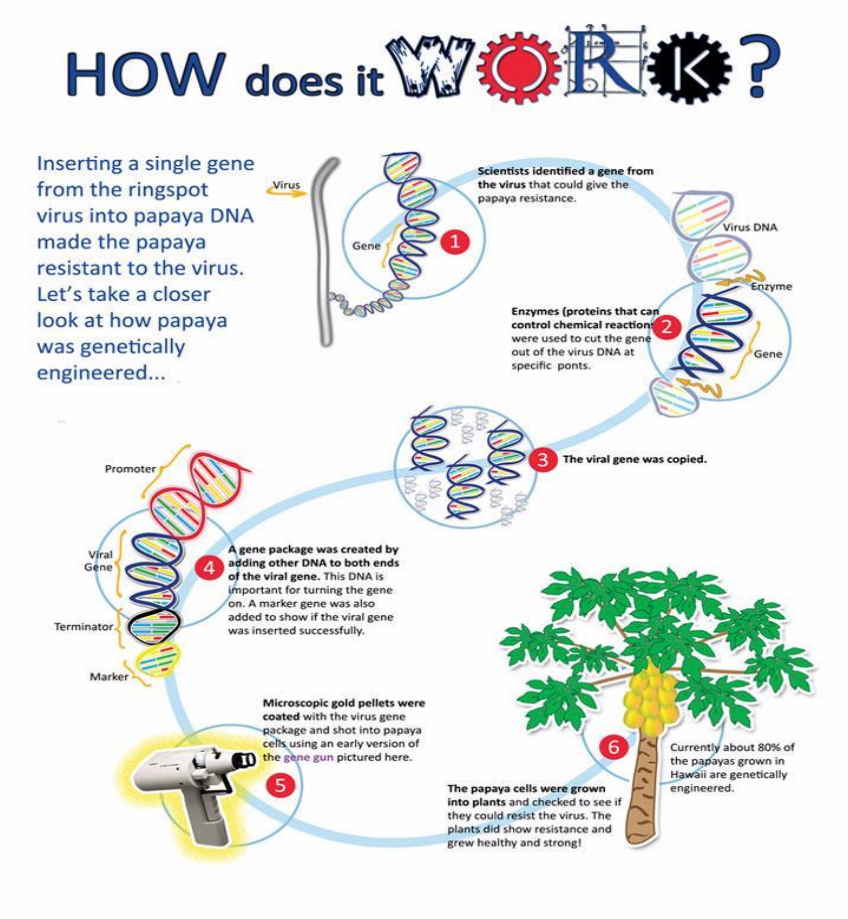


Fig:1.6 Biotechnology in Papaya plant

(Image source: Nature.com)

2.7 APPLICATIONS OF BIOTECHNOLOGY IN MEDICINE

The process of recombinant DNA technology has made an immense impact in the area of healthcare by enabling mass production of safe and more effective therapeutic drugs. Also, this technology does not induce unwanted immunological responses which are very common in similar products isolated from non-human sources.

Note:- Currently, about 30 recombinant therapeutics have been approved for the use of humans all over the world. Moreover, in India, 12 of these are presently being marketed.

i. Insulin

- Insulin is required by diabetic patients to remove excess sugar from the blood. Diabetic patients have a very low level of insulin or no insulin produced by the body. Therefore they need external insulin to control the blood glucose levels.
- Later it was discovered that the insulin produced by the pancreas of the pigs could be used by humans. But there were not enough pigs to provide the quantities of insulin required. This led to the cloning of the human insulin gene.
- The specific gene sequence that codes for human insulin were introduced in E.coli bacteria.
- The gene sequence altered the genetic composition of the E.coli cells. Within 24 hours, several E.coli bacteria containing the recombinant human insulin gene were produced. The recombinant human insulin was isolated from E.coli cells.

ii. Gene Therapy

Gene Therapy holds the most promising answer to the problem of genetic diseases. Gene therapy is used to treat genetic disorders usually by the insertion of a normal gene or correct gene for the defective or inactive gene into an individual with the help of vectors such as retrovirus, adenovirus, and herpes simplex virus. The normal gene replaces the defective or inactive gene and carries out its functions. The therapy has the highest chances of developing a permanent cure if introduced in the earliest stages of life.

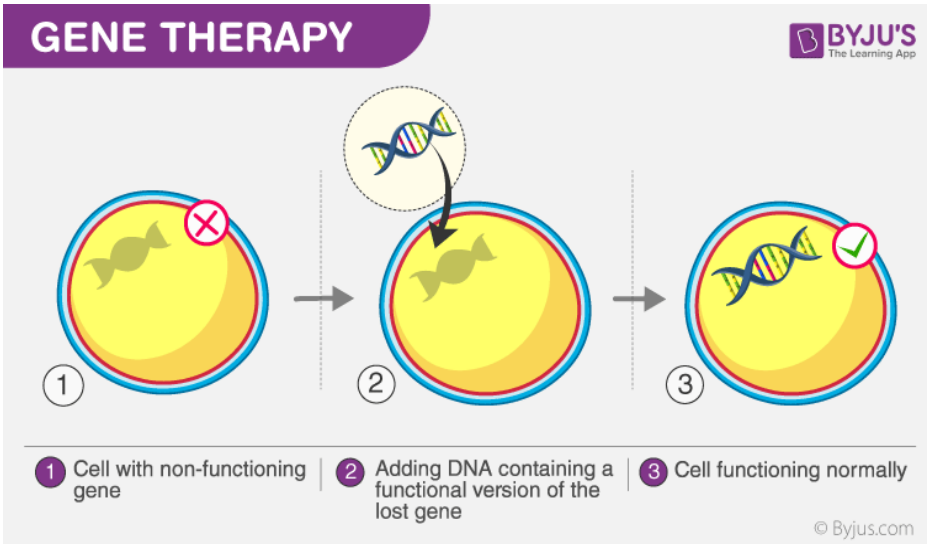
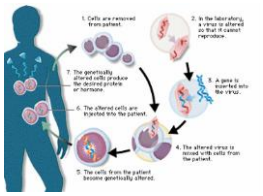
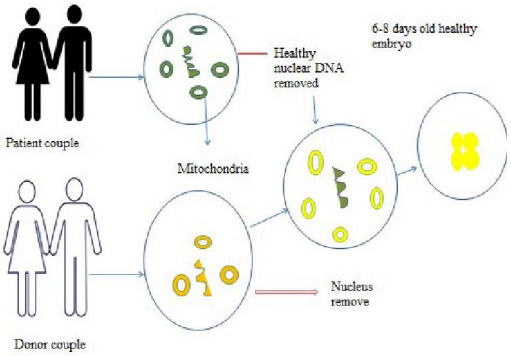


Fig:1.7 Gene Therapy

In the above figure, the cell with the defective gene is injected with a normal gene which helps in the normal functioning of the cell. This technique is employed mainly to fight against the diseases in the human body and also to treat the genetic disorders. The damaged proteins are replaced in the cell by the insertion of DNA into that cell. Generally, the improper protein production in the cell leads to diseases. These diseases are treated using gene therapy techniques. For example, cancer cells contain faulty cells which are different from the normal cells and have defective proteins. Hence, if these proteins are not replaced, this disease would prove to be fatal.

iii. Types of Gene Therapy

Somatic Therapy	Germline Therapy
This type usually occurs in the somatic cells of the human body. This is related to a single person and the only person who has the damaged cells will be replaced with healthy cells.In this method, therapeutic genes are transferred into the somatic cells or the stem cells of the human body. This technique is considered as the best and safest method of	It occurs in the germline cells of the human body. Generally, this method is adopted to treat the genetic, disease causing-variations of genes which are passed from from the parents to their children. The process involves introducing a healthy DNA into the cells responsible for producing reproductive cells, eggs or sperms. Germline gene therapy is not

gene therapy. 	legal in many places as the risks outweigh the rewards. 

Somatic Cells	A somatic cell is any cell of the body except sperm and egg cells. Somatic cells are diploid, meaning that they contain two sets of chromosomes, one inherited from each parent. Mutations in somatic cells can affect the individual, but they are not passed onto offspring.
Germline Cells	Germ cells are cells that create reproductive cells called gametes. Germ cells are also diploid, but they are found only in the gonads. Gonads are the ovaries in females and testes in males. In these organs, females make gametes called eggs, and males make gametes called sperm. Gametes are haploid cells, which means that they have only one set of chromosomes. In humans, gametes have 23 chromosomes.

iv. Applications of Gene Therapy

- It is used in the replacement of genes that cause medical ill-health
- The method generally destroys the problem causing genes
- It helps the body to fight against diseases by adding genes to the human body
- This method is employed to treat diseases such as cancer, ADA deficiency, cystic fibrosis, etc.

v. Molecular Diagnosis

Medical diagnosis is another application of biotechnology in the health sector. Many times the pathogen concentration increases by the time the disease is diagnosed. Hence, early diagnosis and knowledge of pathophysiology are essential for an effective cure. This can be achieved with the help of techniques such as Recombinant DNA Technology, Polymerase Chain Reaction (PCR) and Enzyme-Linked Immunosorbent Assay (ELISA), etc.

vi. Pharmacogenomics

Pharmacogenomics has led to the production of drugs that are best suited to an individual's genetic makeup. It can be applied to diseases such as cancer, depression, HIV, asthma, etc.

vii. Edible Vaccines

Vaccines are obtained by animals and cell cultures. These vaccines contain inactivated pathogens. The transgenic plants can produce antigens that can be used as edible vaccines. Antigenic proteins from several pathogens can be expressed in plants such as tomato and banana. Transgenic sugar beet can treat foot and mouth disease of animals, transgenic bananas and tomatoes can cure diseases such as cholera and hepatitis B.

viii. Transgenic Animal

Transgenic animals are animals with modified genomes. A foreign gene is inserted into the genome of the animal to alter its DNA. This method is done to improve the genetic traits of the target animal. Initially, the improvement of genetic traits was done by selective breeding methods. In this, the animals with desired genetic characteristics were mated to produce an individual with improved genetic characteristics. Since this technique was time-consuming and expensive, it was later replaced by recombinant DNA technology. Transgenesis is the phenomenon in which a foreign gene with desired characteristics is introduced into the genome of the target animal. The foreign gene that is introduced is known as the transgene, and the animal whose genome is altered is known as transgenic. These genes are passed on to successive generations. The transgenic animals are genetically engineered and are also known as genetically modified organisms. The first genetically modified organism was engineered in the year 1980.

2.8 METHODS FOR CREATING TRANSGENIC ANIMALS

i. Physical Transfection

In this method, the gene of interest is directly injected into the pronucleus of a fertilized ovum. It is the very first method that proved to be effective in mammals. This method applied to a wide variety of species. Other methods of physical transfection include particle bombardment, ultrasound, and electroporation.

ii. Chemical Transfection

One of the chemical methods of gene transfection includes transformation. In this method, the target DNA is taken up in the presence of calcium phosphate. The DNA and calcium phosphate co-precipitates, which facilitates DNA uptake. The mammalian cells possess the ability to take up foreign DNA from the culture medium.

iii. Retrovirus-Mediated Gene Transfer

To increase the chances of expression, the gene is transferred utilizing a vector. Since retroviruses can infect the host cell, they are used as vectors to transfect the gene of interest into the target genome.

iv. Viral Vectors

Viruses are used to transfect DNA into the animal cell. The viruses possess the ability to infect the host cell, express well, and replicate efficiently.

v. Bactofection

It is the process by which the gene of interest is transferred into the target gene with the help of bacteria

vi. Examples of Transgenic Animals

Following are the examples of transgenic animals from India

- **Dolly Sheep:** Dolly the sheep was the first mammal to be cloned from an adult cell. In this, the udder cells from a 6-year-old Finn Dorset white sheep were injected into an unfertilized egg from a Scottish Blackface ewe, which had its nucleus removed. The cell was made to fuse by electrical pulses. After the fusion of the nucleus of the cell with the egg, the resultant embryo was cultured for six to seven days. It was then implanted into another Scottish Blackface ewe which gave birth to the transgenic sheep, Dolly.

- **Transgenic Mice:** Transgenic mice are formed by injecting DNA into the oocytes or one or two-celled embryos obtained from female mice after hormonal treatment. After injecting the DNA, the embryo is implanted into the uterus of receptive females. It is developed by the National Institute of Immunology and International Centre For Genetic engineering and Biotechnology

vii. Applications of Transgenic Animals

The transgenic animals are created because of the benefits they provide to the man. Let us discuss a few of them here.

viii. Normal Physiology and Development

In transgenic animals, a foreign gene is introduced due to which the growth factor is altered. Hence, these animals facilitate the study of gene regulation and their effect on the everyday functions of the body.

2.9 STUDY OF DISEASES

Transgenic animals are specially designed to study the role of genes in the development of certain diseases. Moreover, to devise a cure for these diseases, the transgenic animals are used as model organisms. These transgenic models are used in research for the development of medicines. For example, we have transgenic models for diseases such as Alzheimer's and cancer.

i. Biological Products

Several biological products, such as medicines and nutritional supplements, are obtained from transgenic animals. Research for the manufacture of medicines to treat diseases such as phenylketonuria (PKU) and hereditary emphysema is going on. The first transgenic cow, Rosie, in 1997, produced milk that was rich in human protein (2.4 grams per liter). This milk contains the human gene alpha-lactalbumin and could be given to babies as an alternative to natural cow milk.

ii. Vaccine Safety

- Transgenic animals are used as model organisms for testing the safety of vaccines before they are injected into humans. This was conventionally done on monkeys.

ELISA Technique

ELISA is a basic enzyme-linked immunosorbent assay (also shortened as EIA: Enzyme Immunoassay) that is carried out to detect and measure antibodies in the blood. Antibodies are blood proteins produced in response to a specific antigen. It helps to examine the presence of antibodies in certain infectious disorders.

ELISA is a distinguished analysis compared to other antibody-assays as it yields quantitative results and separation of non-specific and specific interactions that take place through serial binding to solid surfaces, which is normally a polystyrene multiwell plate.

iii. Polymerase Chain Reaction (PCR)

Polymerase chain reaction (PCR). The polymerase chain reaction is another widely used DNA manipulation technique, one with applications in almost every area of modern biology. PCR reactions produce many copies of a target DNA sequence starting from a piece of template DNA. This technique can be used to make many copies of DNA that are present in trace amounts (e.g., in a droplet of blood at a crime scene).

2.10INDUSTRIAL BIOTECHNOLOGY

Industrial biotechnology is one of the most promising new approaches to pollution prevention, resource conservation, and cost reduction. It is often referred to as the third wave in biotechnology. If developed to its full potential, industrial biotechnology may have a larger impact on the world than health care and agricultural biotechnology. It offers businesses a way to reduce costs and create new markets while protecting the environment. Also, since many of its products do not require the lengthy review times that drug products must undergo, it's a quicker, easier pathway to the market. Today, new industrial processes can be taken from lab study to commercial application in two to five years, compared to up to a decade for drugs.

The application of biotechnology to industrial processes is not only transforming how we manufacture products but is also providing us with new products that could not even be imagined a few years ago. Because industrial biotechnology is so new, its benefits are still not well known or understood by the industry, policymakers, or consumers.

From the beginning, industrial biotechnology has integrated product improvements with pollution prevention. Nothing illustrates this better than the way industrial biotechnology solved the phosphate water pollution problems in the 1970s caused by the use of phosphates in laundry detergent. Biotechnology companies developed enzymes that remove stains from clothing better than phosphates, thus enabling replacement of a polluting material with a non-polluting biobased additive while improving the performance of the end product. This innovation dramatically reduced phosphate-related algal blooms in surface waters around the globe and simultaneously enabled consumers to get their clothes cleaner with lower wash water temperatures and concomitant energy savings.

Rudimentary industrial biotechnology dates back to at least 6000 B.C. when Neolithic cultures fermented grapes to make wine, and Babylonians used microbial yeasts to make beer. Over time, humanity's knowledge of fermentation increased, enabling the production of cheese, yogurt, vinegar, and other food products. In the 1800s, Louis Pasteur proved that fermentation was the result of microbial activity. Then in 1928, Sir Alexander Fleming extracted penicillin from mold. In the 1940s, large-scale fermentation techniques were developed to make industrial quantities of this wonder drug. Not until after World War II, however, did the biotechnology revolution begin, giving rise to modern industrial biotechnology.

Since that time, industrial biotechnology has produced enzymes for use in our daily lives and the manufacturing sector. For instance, a meat tenderizer is an enzyme, and some contact lens cleaning fluids contain enzymes to remove sticky protein deposits. In the main, industrial biotechnology involves the microbial production of enzymes, which are specialized proteins. These enzymes have evolved in nature to be super-performing biocatalysts that facilitate and speed-up complex biochemical reactions. These amazing enzyme catalysts are what make industrial biotechnology such a powerful new technology.

Industrial biotechnology involves working with nature to maximize and optimize existing biochemical pathways that can be used in manufacturing. The industrial biotechnology revolution rides on a series of related developments in three fields of study of detailed information derived from the cell: genomics, proteomics, and bioinformatics. As a result, scientists can apply new techniques to a large number of microorganisms ranging from bacteria, yeasts, and fungi to marine diatoms and protozoa.

Industrial biotechnology companies use many specialized techniques to find and improve nature's enzymes. Information from genomic studies on microorganisms is helping researchers capitalize on the wealth of genetic diversity in microbial populations. Researchers first search for enzyme-producing microorganisms in the natural environment and then use DNA probes to search at the molecular level for genes that produce enzymes with specific biocatalytic capabilities. Once isolated, such enzymes can be identified and characterized for their ability to function in specific industrial processes. If necessary, they can be improved with biotechnology techniques.

Many biocatalytic tools are rapidly becoming available for industrial applications because of the recent and dramatic advances in biotechnology techniques. In many cases, the biocatalysts or whole-cell processes are so new that many chemical engineers and product development specialists in the private sector are not yet aware that they are available for deployment. This is a good example of a "technology gap" where there is a lag between availability and widespread use of new technology. This gap must be overcome to accelerate progress in developing more economical and sustainable manufacturing processes through the integration of biotechnology. "New Biotech Tools for a Cleaner Environment" provides dramatic illustrations of what these powerful new tools can do. The report aims to spark more interest in this powerful technology, to help close this technology gap, and facilitate progress toward a more sustainable future.

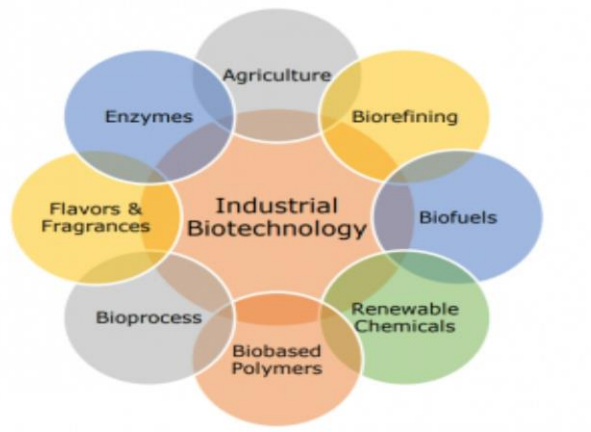


Fig:1.9 Industrial Biotechnology

(Image Source:nuclineers.com)

2.11ENVIRONMENTAL BIOTECHNOLOGY

Environmental biotechnology is biotechnology that is applied to and used to study the natural environment. Environmental biotechnology could also imply that one tries to harness biological processes for commercial uses and exploitation.

The International Society for Environmental Biotechnology defines environmental biotechnology as "**the development, use and regulation of biological systems for remediation of contaminated environments (land, air, water), and environment-friendly processes (green manufacturing technologies and sustainable development).**

Significance of Environmental Biotechnology in Sustainable Development and climate change mitigation

There have been increasing calls for the advancement of small-scale agro-ecological farming systems and technology in order to achieve food security, climate change mitigation, climate change adaptation and the realization of the Millennium Development Goals. Environmental biotechnology has been shown to play a significant role in **agroecology** in the form of zero waste agriculture and most significantly through the operation of over 15 million biogas digesters worldwide.

2.12BIOREMEDIATION

Bioremediation is a biotechnical process, which abates or cleans up contamination. It is a type of waste management technique which involves the use of organisms to remove or utilize the pollutants from a polluted area.

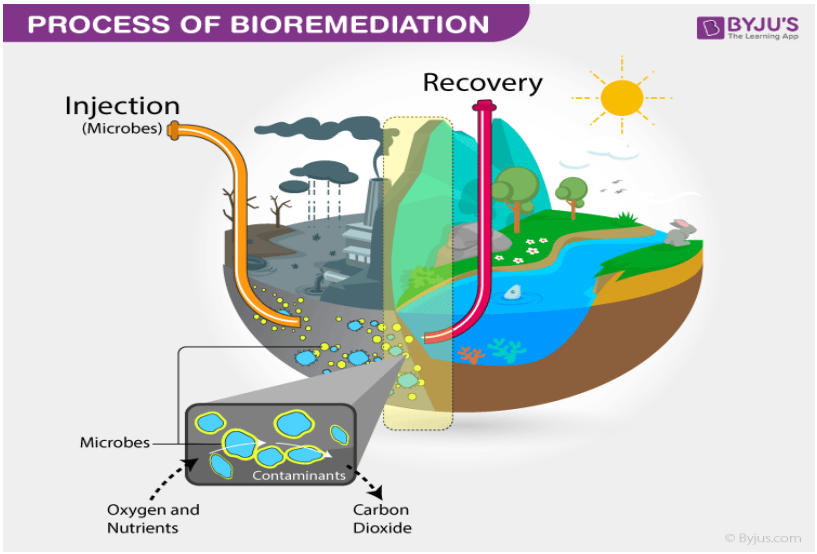


Fig: 1.9 Bioremediation technique

There are several remedies where contaminated water or solid is purified by chemical treatment, incineration, and burial in a landfill. There are other types of waste management technique which include solid waste management, nuclear waste management, etc. Bioremediation is different as it uses no toxic chemicals. Microorganisms like Bacteria and Fungi are the main role players when it comes to executing the process of Bioremediation. Bacteria are the most crucial microbes in this process as they break down the waste into nutrients and organic matter. Even though this is an efficient process of waste management, bioremediation cannot destroy 100% contaminants. Bacteria can easily digest contaminants

like chlorinated pesticides or clean oil spills but microorganisms fail to destroy heavy metals like lead and cadmium.

2.13 TYPES OF BIOREMEDIATION

IN-SITU	EX - SITU
Bioventing: supply of air and nutrients through wells to contaminated soil to stimulate the growth of indigenous bacteria. It is used for simple hydrocarbons and can be used where the contamination is deep under the surface.	**Land farming**: contaminated soil is excavated and spread over a prepared bed and periodically tilled until pollutants are degraded. The goal is to stimulate indigenous biodegradative microorganisms and facilitate their aerobic degradation of contaminants.
Biosparging: Injection of air under pressure below the water table to increase groundwater oxygen concentrations and enhance the rate of biological degradation of contaminants by naturally occurring bacteria	**Biopiles**: it is a hybrid of land farming and composting. Essentially, engineered cells are constructed as aerated compost piles. Typically used for treatment of surface contamination with petroleum hydrocarbons
Bioaugmentation - At times, there are certain sites where microorganisms are required to extract the contaminants. For example – municipal wastewater. In these special cases, the process of bioaugmentation is used. There's only one major drawback in this process. It almost becomes impossible to control the growth of microorganisms in the process of removing the particular contaminant	**Bioreactors**: it involves the processing of contaminated solid material (soil, sediment, sludge) or water through an engineered containment system.
Intrinsic Bioremediation - The process of intrinsic bioremediation is most effective in the soil and water because of these two biomes which always have a high probability of being full of contaminants and toxins. The process of intrinsic bioremediation is mostly used in underground places like underground petroleum tanks. In such a place, it is difficult to detect a leakage and contaminants and toxins can find their way to enter through these leaks and contaminate the petrol. Thus, only microorganisms can remove the toxins and clean the tanks.	**Composting**: Composting is nature's process of recycling decomposed organic materials into a rich soil known as compost

2.14 PHYTOREMEDIATION

In this scenario, plants are directly used to clean up or contain contaminants in the soil. This method of bioremediation will help mitigate the environmental problem without the need to excavate the contaminant material and dispose of it elsewhere.

E.g:- Poplar trees are used for removal of toxic substances from ground(often used in USA)

Also radioactive elements have been phytoremediation using Sunflower plants

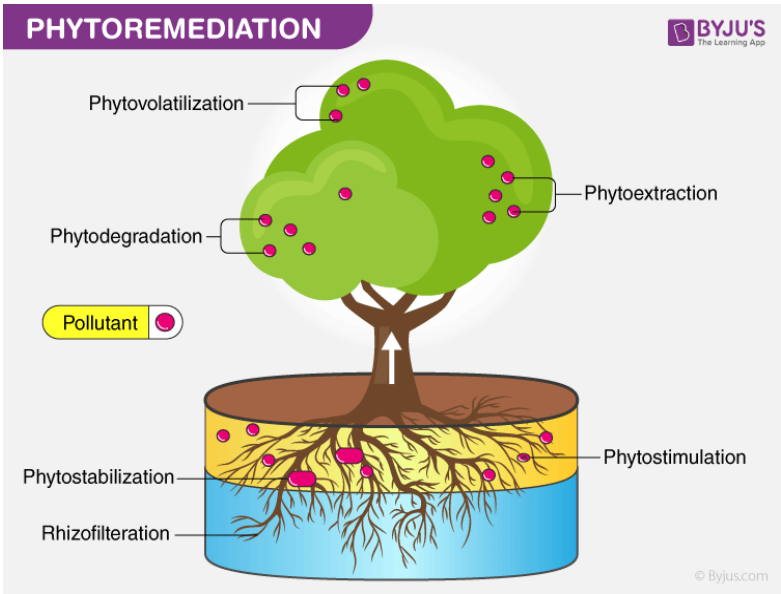


Fig: 1.10 Phytoremediation Technique

(Image source: Byjus)

OTHER APPLICATIONS OF BIOTECHNOLOGY

(a) Fermentation is an ancient invention of biotechnology. Alcohol and bread have been produced for ages with the help of microorganisms such as yeast. In today's scenario, the cultures have been purified and genetically refined to produce high-quality food products.

(b) Crop improvement by crossing the plant breeds with desired traits is another application of biotechnology in the agriculture sector.

(c) Transgenic plants are genetically engineered to produce plants with desired characteristics.

(d) Tissue culture is another application of biotechnology to produce a large number of plants with an explanation. It also helps in increasing the number of endangered plant species.

(e) It is also helpful in forensics for the identification of criminals, or paternity disputes.

2.15 BIOTECHNOLOGY AND ETHICS

The manipulation of living organisms by the human race has been subject to questioning especially regarding moral and ethical issues. Thus it cannot go on any further, without regulation. **Some ethical standards** are required to evaluate the morality of all human activities that might help or harm living organisms.

Going beyond the morality of such issues, the biological significance of such things is also important. Genetic modification of organisms can have unprecedented and unpredictable results when such organisms are introduced into the ecosystem.

It is essential that biotechnology innovations cautiously tested and analyzed before they are released for commercial use. Some methods like Clinical trials and government regulation help us to ensure that the products of Biotechnology that are released into the market are safe and effective. However, sometimes new information becomes available that makes companies and government agencies reconsider the safety or utility of innovation. This happens at times when a medication is occasionally withdrawn from the market. Apart from this certain biological Innovation and nobody technique of knowledge which raise ethical questions about the use of these methodologies.

Privacy is one of the most important concerns arising out of it. Should a health insurance company be able to charge you more if you have a gene variant that makes you likely to develop a disease? How would you feel if your school or employer had access to your genome?

There are also concerns about **safety, health effects, and ecological concerns related to technology** such as those associated with genetically engineered crops.

Therefore, under the **Environment Protection Act (1986),** the Government of India has set up organizations such as **GEAC (Genetic Engineering Appraisal Committee**), which will make decisions regarding the validity of G.M. research and the safety of introducing GM-organisms for public services.

The modification/usage of living organisms for public services (as food and medicine sources, for example) has also created problems with patents granted for the same. There is growing public anger towards certain companies being granted patents for products and

technologies which make use of the genetic materials, plants, and other biological resources that have long been identified, developed, and used by farmers and indigenous people of a specific region/country.

Rice is an important food grain, the presence of which goes back thousands of years in Asia's agricultural history. There are an estimated 200,000 varieties of rice in India alone. The diversity of rice in India is one of the richest in the world. Basmati rice is distinct for its unique aroma and flavor, and 27 documented varieties of Basmati are grown in India. There is a reference to Basmati in ancient texts, folklore, and poetry, as it has been grown for centuries. In 1997, an American company got patent rights on Basmati rice through the U.S. Patent and Trademark Office. This allowed the company to sell a 'new' variety of Basmati, in the U.S. and abroad. This 'new' variety of Basmati had been derived from Indian farmer's varieties. Indian Basmati was crossed with semi-dwarf varieties and claimed as an invention or a novelty. The patent extends to functional equivalents, implying that other people selling Basmati rice could be restricted by the patent.

Several attempts have also been made to patent uses, products, and processes based on Indian traditional herbal medicines, e.g., turmeric neem. If we are not vigilant and we do not immediately counter these patent applications, other countries/individuals may encash on our rich legacy, and we may not be able to do anything about it

i. Biopiracy

Biopiracy is the term used to refer to the use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned without compensatory payment.

Most of the industrialized nations are rich financially but poor in **biodiversity and traditional knowledge**. In contrast, the developing and the underdeveloped world is rich in biodiversity and traditional knowledge related to bio-resources.

Traditional knowledge related to bio-resources can be exploited to develop modern applications and can also be used to save time, effort, and expenditure during their commercialization.

There has been a growing realization of the injustice, inadequate compensation, and benefit-sharing between developed and developing countries. Therefore, some nations are developing laws to prevent such unauthorized exploitation of their bio-resources and traditional knowledge.

2.16SCOPE OF BIOTECHNOLOGY

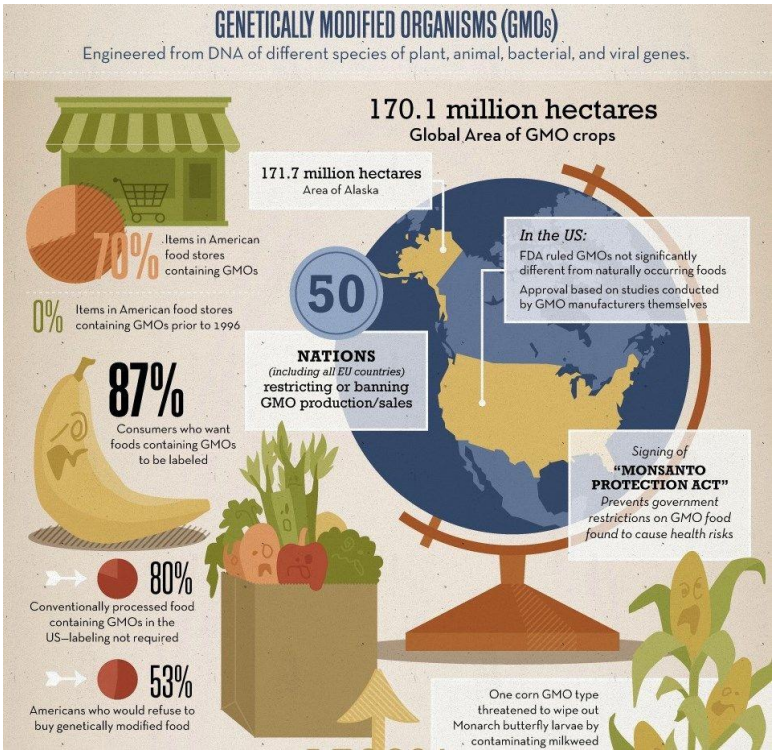
Biotechnology is applied to various fields and many industries such as food, pharmaceuticals, medicine, agriculture, etc.. It has its scope in both research and engineering.

Genetic engineering has helped in the production of therapeutic proteins as well as biological organisms. Biotechnology has made major advances in molecular biology and industrial biotechnology.

The scope of biotechnology is extended to various branches of Biology. Some of these include tissue culture, development of transgenic plants and animals, development of antibodies, etc. The USA itself has established more than 200 companies such as Biogen, Cetus, Hybritech, etc.

i. GENETICALLY ENGINEERED ORGANISMS

"Genetically modified organisms are those that have their DNA altered in some way through genetic engineering."



(Image source: alltop.com)

Genetically modified organisms (GMOs) or transgenic organisms are those in which DNA from the desired organism is inserted in the laboratory. They are created in the laboratory using scientific methods reproductive cloning or Recombinant DNA technology.

ii. Bt CROPS

<u>Definition</u>:- Bt crops are transgenic crops that are genetically engineered from the DNA of bacterium Bacillus thuringiensis.

Bt Crops are transgenic crops that produce the same toxin as the bacterium Bacillus thuringiensis in the plant cell, thereby, protecting the crops from pests. The bacterium secretes specific proteins known as "cry proteins" that are toxic to insects. A few of the Bt crops include cotton, brinjal, corn, etc.

When an insect feeds on the transgenic plants, the toxic cry protein present in the plants crystallizes the digestive system of insects that leads to the death of the organism. However, it has no harmful effects on the human digestive system.

iii. TYPES OF Bt CROPS:

Bt Cotton	Bt Brinjal
• The Bt cotton variety is genetically transformed with the Bt gene to protect the plants from bollworm, a major pest of cotton. • The worms present on the leaves of Bt cotton become lethargic and sleepy and thus, cause less damage to the plants. The toxic proteins produced by the crops are ingested by the pests which kill them, thereby, protecting the crops.	• Bt brinjal is also produced by genetic transformation of a crystal protein gene cry 1 Ac from the bacterium Bacillus thuringiensis. Bt brinjal was developed to provide resistance against lepidopteran insects. • The proteins produced by Bt genes bind to the receptors present on the insect's membrane, which forms pores on the membranes. This disrupts the digestive process and leads to the death of the insect

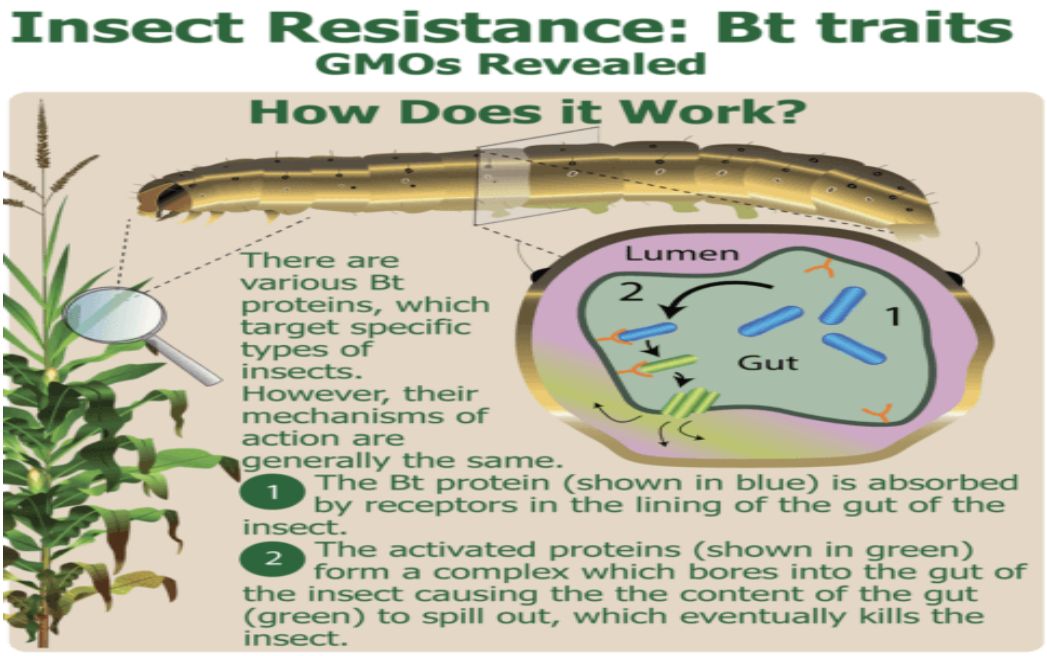


Fig:1.11 Bt Crops (Mechanism)

(Image source: Biofortified.org)

iv. Advantages of Bt crops

Following are the major advantages of Bt crops:

- It helps in improving the crop yield, thereby raising the farmer's income. This results in increased farm production.
- They help in controlling soil pollution as the use of synthetic pesticides is reduced.
- Bt crops help in protecting beneficial insects.
- It can easily feed an increasing population due to increased yields in a short time.
- It leads to the production of disease-free crops owing to the reduction of pesticides.
- It leads to more productivity in a small area of land.

v. Disadvantages of Bt Crops

Bt crops have a few disadvantages as well:

- Bt crops are costlier than naturally grown crops.
- It can disrupt the natural process of gene flow.
- The pests might become resistant to the toxins produced by these crops, and the crop production might decline.

- Threats to traditional knowledge and farming practices due to increased competitiveness from big capitalist
- Seed Monopolies by big companies
- Issues of Seed survival after the first generation

vi. Monsanto Genetically Modified Corn

Monsanto's genetically modified Bt corn is having its roots munched by super-rootworms and other superbugs, putting corn crops at risk. Yet, more evidence is found of the dangers to human health. The strain of corn, engineered to kill the larvae of beetles, such as the corn rootworm, contains a gene copied from an insect-killing bacteria called Bacillus thuringiensis, or Bt. Monsanto's G.M. Bt corn is equipped with a gene from soil bacteria called Bt or Bacillus thuringiensis. This produces the Bt-toxin in the corn. The pesticide breaks open the stomach of certain insects and kill them.

This Bt corn was introduced into the food supply in the late 1990s, and problems have been occurring ever since. However, the Environmental Protection Agency (EPA) was warning against this variety due to apprehensions about ill effects on the environment and human health. Monsanto and the EPA swore that the genetically engineered corn would only harm insects. They stated that the Bt-toxin produced inside the plant would be destroyed in the human digestive system. They said it would not have any impact on the health of consumers. Unfortunately, they have been proven wrong, because not only is Bt corn producing resistant "super pests", researchers have also found that the Bt-toxin can badly affect human health.

vii. Issues with Bt Cotton

- It is an insect-resistant transgenic crop that is designed to combat the **bollworm**.
- Bt cotton was created through genetic alteration of the cotton genome to express a microbial protein from the bacterium Bacillus thuringiensis.
- In short, the transgene inserted into the plant's genome produces toxin crystals that the plant would not normally produce which, when ingested by a certain population of organisms, dissolves the gut lining, leading to the organism's death.
- Although the Bollgard 2 technology for cotton was supposed to protect crops against the pink bollworm, **the pest has grown resistant to the toxins produced by this trait only in India.**
- It is argued by research and scientific lobby that Bt-cotton seeds are not suitable under Monsoon conditions and unlike other Cotton-growing countries where open-

pollinated cotton varieties are grown, Indian cotton farmers only opt for hybrid varieties.

viii. Recent developments

GM Mustard

Dhara Mustard Hybrid-11, otherwise known as DMH - 11, is a genetically modified hybrid variety of the mustard species Brassica juncea. It was developed by Professor Deepak Pental from the University of Delhi, to reduce India's demand for edible oil imports. DMH - 11 was created through transgenic technology, primarily involving the Bar, Barnase, and Barnstar gene system. The Barnase gene confers male sterility, while the Barnstar gene restores DMH - 11's ability to produce fertile seeds. The insertion of the third gene Bar enables DMH - 11 to produce phosphinothricin-N- acetyl-transferase, the enzyme responsible for Glufosinate resistance.

This hybrid mustard variety has come under intense public scrutiny, mainly due to concerns regarding DMH - 11's potential to affect the environment as well as consumer health adversely. DMH - 11 was found not to pose any food allergy risks, and has demonstrated increased yields over existing mustard varieties. Conflicting details and results regarding the field trials and safety evaluations conducted on DMH - 11 have delayed its approval for commercial cropping.

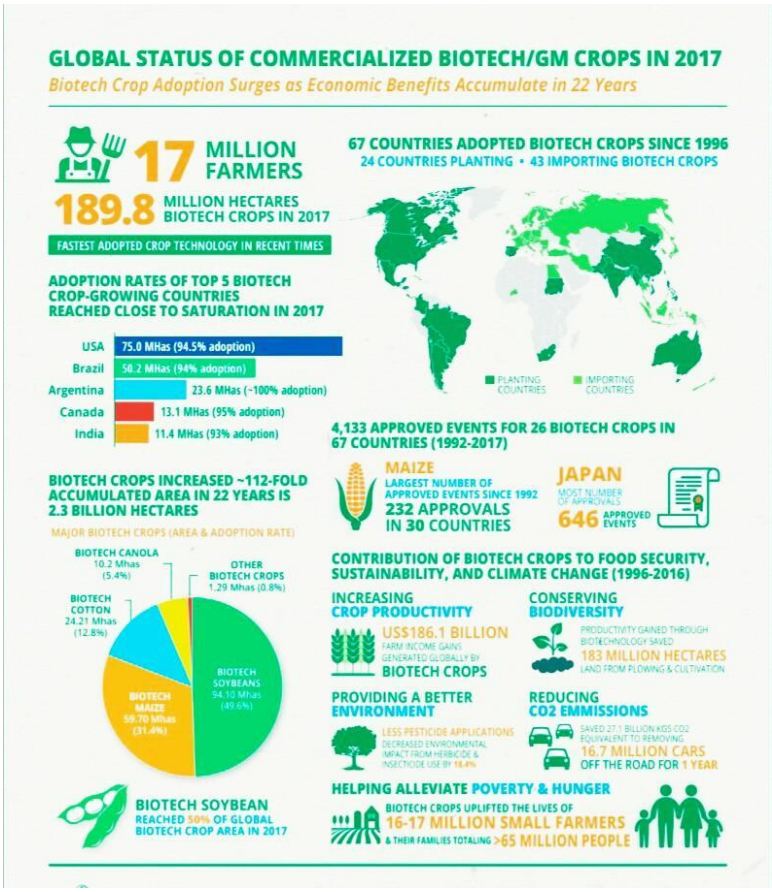


Fig:1.12 GMO Crops worldwide

(Image Source: isaaa.org)

VACCINES

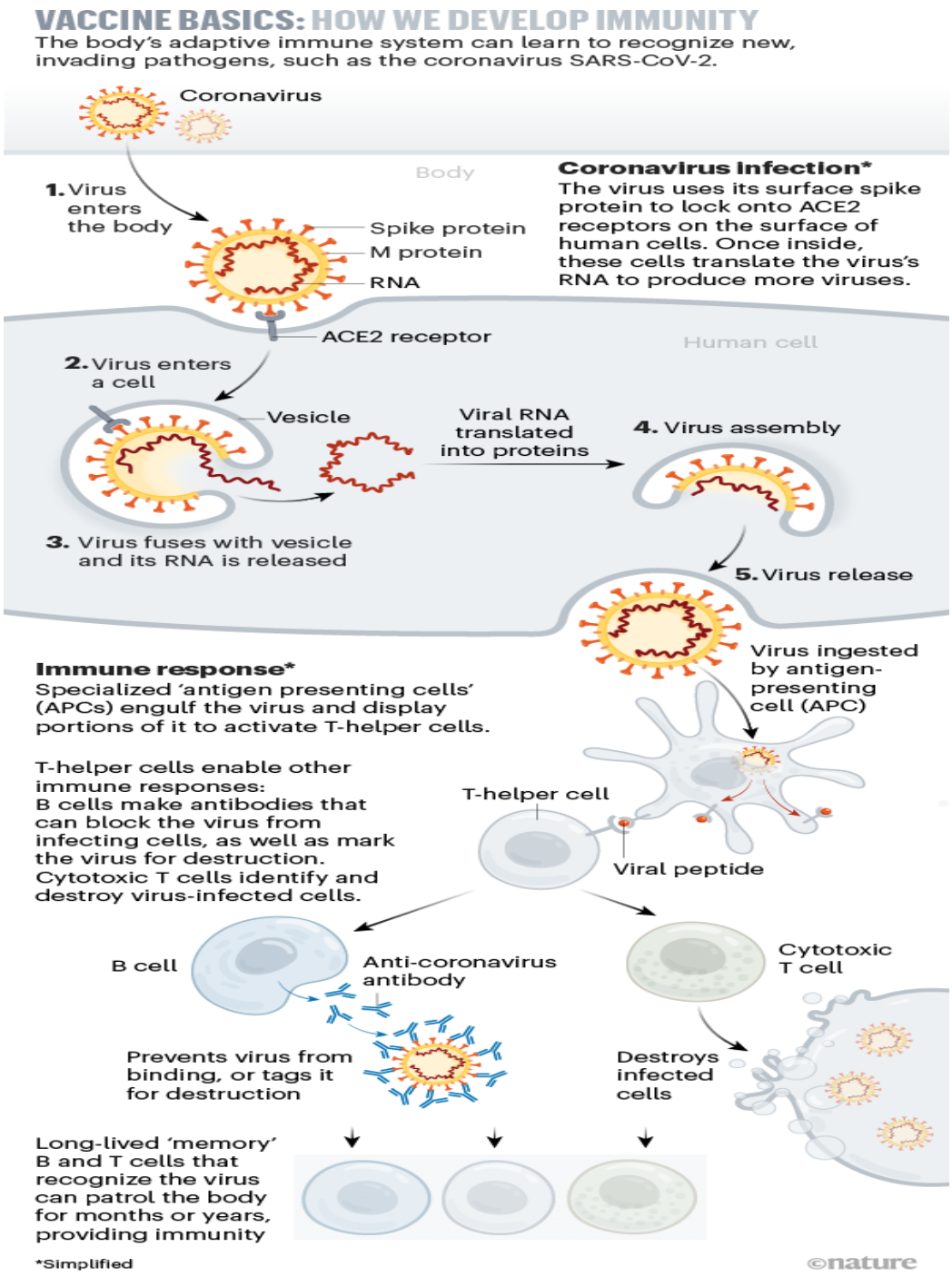
DNA Vaccines

- DNA vaccination is a technique for protecting an animal against disease by injecting it with genetically engineered DNA, so cells directly produce an antigen, resulting in a protective immunological response.
- Several DNA vaccines have been released for veterinary use, and there has been promising research using the vaccines for viral, bacterial and parasitic diseases, as well as to several tumour types.
- Although only one DNA vaccine has been approved for human use, DNA vaccines may have several potential advantages over conventional vaccines, including the ability to induce a wider range of immune response types.

- Field of DNA vaccination is developing very rapidly, the vaccines that are being developed use not only DNA but also the adjuncts that assist DNA target specific cells Or that may Act as adjuvants in stimulating or directing the immune response.
- However, there are still several aspects of the development and functioning of DNA vaccines that are yet not understood properly. Still, it has not impeded the research and further progress towards working on its development.
- The first such vaccines that have been approved for use are likely to utilize plasmid DNA from bacterial cells. In future, it is believed that the vaccines mainly use RNA derived molecules or nucleic acid molecules.

Other Types of Vaccines

In the wake of Coronavirus Pandemic, vaccine Development has taken a front seat in the global research community. Several Nations have been in the vaccine Development Programme and many who are not actively involved are supporting the initiatives by way of manpower, funding, logistics etc.More than 90 vaccines are being developed against SARS-CoV-2 by research teams in companies and universities across the world. Researchers are trialling different technologies, some of which haven't been used in a licensed vaccine before. All vaccines aim to expose the body to an antigen that won't cause disease, but will provoke an immune response that can block or kill the virus if a person becomes infected. There are at least eight types being tried against the coronavirus, and they rely on different viruses or viral parts.



(Image source: NATURE)

i. Virus Vaccines

These vaccines are developed using the virus itself, in an inactivated or weakened form. Many existing vaccines are made in this way, such as those against measles and polio, but they require extensive safety testing.

In a **weakened vaccine**, the virus which is being used is passed through human or animal cells until it picks up mutations that make it less potent to cause diseases.

In the case of **Inactivated Vaccine**, the virus is rendered uninfectious using chemicals such as formaldehyde or heat.

Viral Vector Vaccines:

In viral Vector Vaccines, the virus is Genetically engineered so that it can produce proteins in the body. They are gradually weakened so that they can't cause any disease.

There are two types of viral Vector Vaccines:-

Replicating Viral Vector Vaccines: The recently developed Ebola Vaccine is an example of this; which replicates within cells. These Vaccines are safe and provoke strong immune responses.

Non replicating Viral Vector: These Vaccines have been useful in heme therapy. They utilize booster shots to induce long-lasting immunity.

ii. Nucleic Acid Vaccines

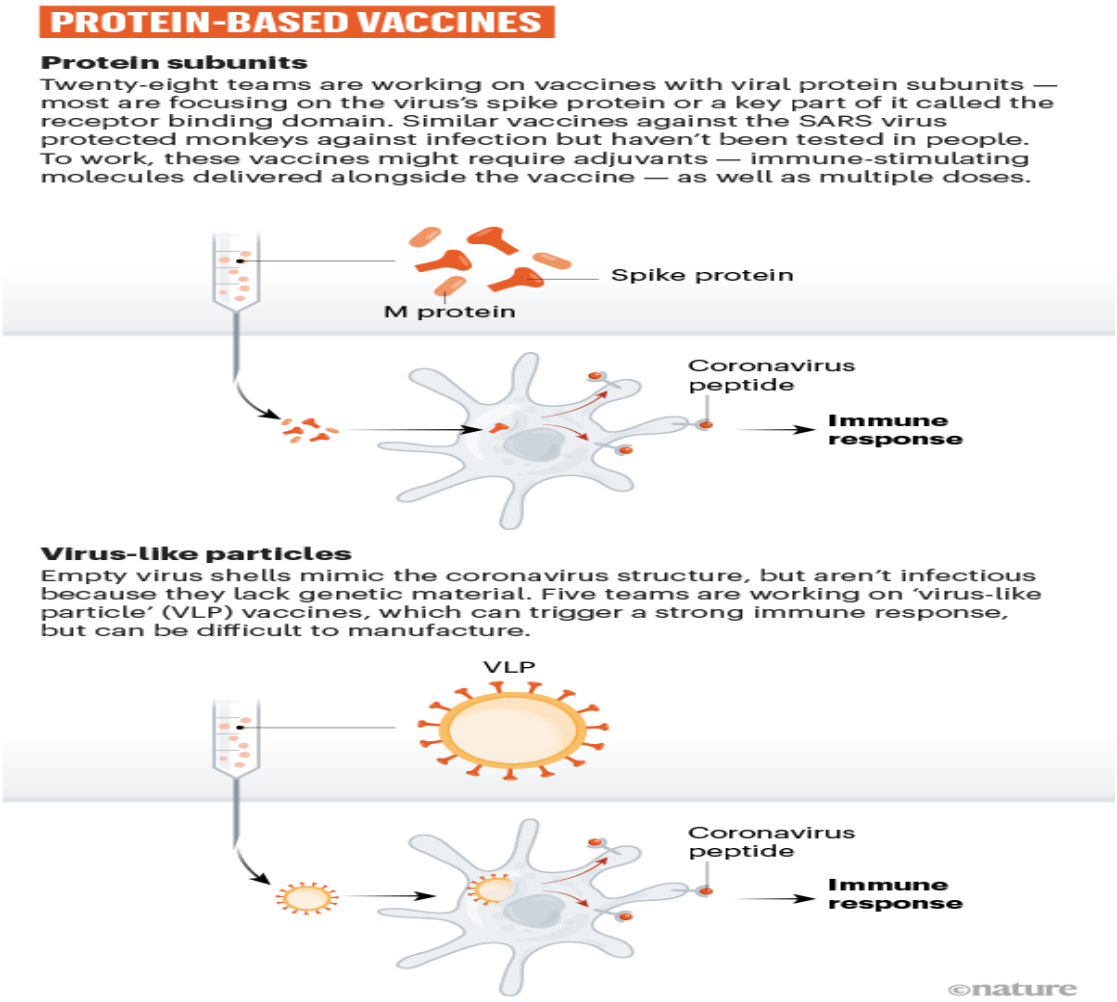
In these Vaccines, the nucleic acid is inserted into human cells, which then churn out copies of the virus protein; most of these vaccines encode the virus's spike protein.

There are **DNA Vaccines** that use the process of electroporation for creating pores membranes to increase the uptake of DNA into cells. While the **RNA Vaccines** are encased in lipid coats so that it can enter cells.

Both DNA and RNA Vaccines are easy to develop as their production involves alterations in genetic material only and not the viruses. However, they are unproven.

iii. Protein-Based Vaccines

In these Vaccines fragments of protein or protein shells that mimic the virus are inserted. Two versions of these Vaccines are generally under trial; one uses Protein subunits while the other version uses Virus-like particles.



(Image source:Nature)

iv. STAGES OF VACCINE DEVELOPMENT

It is often seen that in almost all the regulatory regimes, vaccine development takes several years and typically proceeds through three phases of clinical trials.

Phase 1: In this phase, trial Vaccine is administered to Small groups of people.

Phase 2: During this phase, Clinical study is extended and the vaccine is administered to people who have characteristics (like physical health and age) similar to those people for whom the new vaccine is intended.

Phase 3: In this phase Vaccine is given to a large pool of people and its efficacy and safety are tested. During this phase, participants who engage in trials either receive the vaccine or a placebo.

Note:- Placebo is something that looks similar to real treatment but it is not. For example- sugar pills and saline injections.

The effectiveness of Vaccines is analyzed after comparing the prevalence of infection in the group that was given the vaccine with the one which received a placebo.
The hypothesis that those in the vaccine group will be infected significantly less is thus tested.

2.17 BIOINFORMATICS

Bioinformatics is an emerging branch of biological science that emerged by the combination of both biology and information technology. It is an interdisciplinary field of study that uses Biology, Chemistry, Mathematics, Statistics, and Computer Science that are merged to form a single discipline. This sector is mainly involved in analyzing biological data, developing new software using biological tools.

According to the NCBI- National Center for Biotechnology Information, the branch of NLM- National Library of Medicine and NIH- National Institutes of Health, defines **Bioinformatics as the analysis, collection, classification, manipulation, recovery, storage and visualization of all biological information using computation technology.**

v. Applications of BIOINFORMATICS

Few of the Applications of Bioinformatics are:

- In Gene therapy.
- In Evolutionary studies.
- In Microbial applications.
- In Prediction of Protein Structure.
- For the Storage and Retrieval of Data.
- In the field of medicine, used in the discovery of new drugs.
- In Biometrical Analysis for identification and access control for improvising crop management, crop production, and pest control.

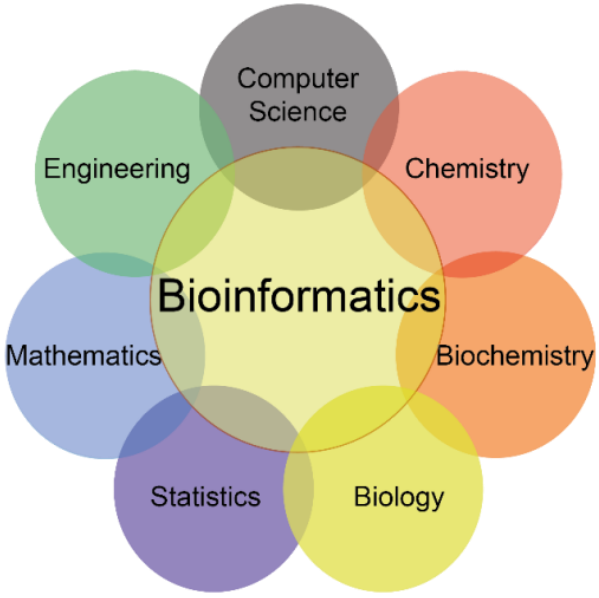


Fig: 1.13 Bioinformatics

(Image *Source:techgetz.com)*

Bioinformatics is mainly used to extract knowledge from biological data through the development of algorithms and software.	A significant application of bioinformatics can be found in the fields of precision and preventive medicines, which is mainly focused on developing measures to prevent, control and cure dreadful infectious diseases.
Bioinformatics is widely applied in the examination of Genomics, Proteomics, 3D structure modelling of Proteins, Image analysis, Drug designing and a lot more	The main aim of Bioinformatics is to increase the understanding of biological processes.

2.18EPIDEMIOLOGY

Epidemiology is the study of the distribution and determinants of health-related status among specific populations and the application of that study to the control of health problems.

Aims and Objectives of Epidemiology Study:

- Discover the agent, host, and environmental factors that affect health
- Determine the relative importance of causes of illness, disability, and death

- Identify those segments of the population that have the greatest risk from specific causes of ill health
- Evaluate the effectiveness of health programs and services in improving population health.

2.19 BIOSIGNATURE

A biosignature can be defined as any substance like isotope, molecules, among others, or phenomenon that provides scientific evidence of past or present life. Certain attributes of life that can be measured include its complex physical or chemical structures and its use of free energy and the production of biomass and wastes.
A biosignature can provide evidence for living organisms outside the Earth and can be directly or indirectly detected by searching for their unique byproducts.

For example, the presence of methane in the atmosphere of Mars is an area of ongoing research and a highly contentious subject. Because it tends to be destroyed in the atmosphere by photochemistry, the presence of excess methane on a planet can be an indication that there must be an active source. With life being the strongest source of methane on Earth, observing a disequilibrium in the methane abundance on another planet could be a viable biosignature.

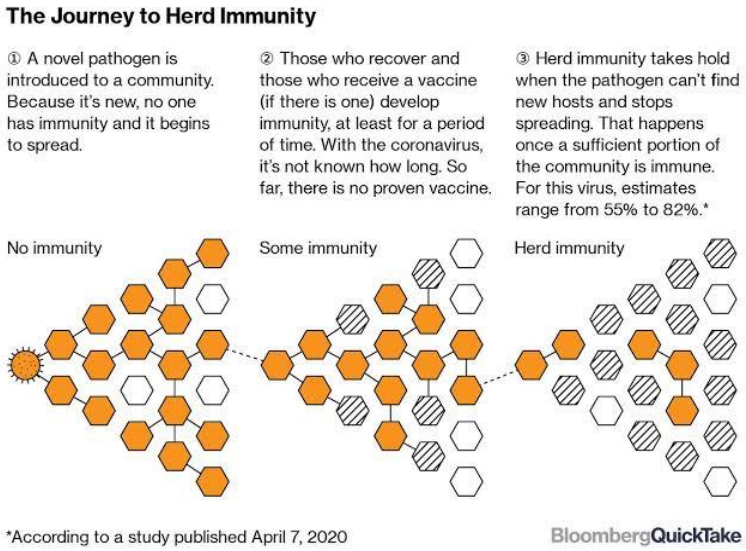
2.20 HERD IMMUNITY

Herd immunity is a concept that is generally described in the context of a vaccine. Herd immunity refers to preventing an infectious disease from spreading by immunizing a certain percentage of the population. While the concept is most commonly used in the context of vaccination, herd immunity can also be achieved when enough people have become immune after being infected. The basic process behind this is If some percentage of the population gets immune, then members of that population who get infection can no longer infect another person. In this way, the chain of infection will be broken through the community (“herd”), and it will prevent the disease from reaching those who are the most vulnerable.

Generally, there are two ways of attaining herd immunity:-

- Firstly, through mass vaccinations

- Secondly, through the infection when a person gets infected and after a while, they develop antibodies to fight the infection and thus become immune to it



(Image source: Bloomberg)

Issues and Concerns Related To Herd Immunity:

In case of any disease which does not have a vaccine like that of Coronavirus, development of herd immunity right away would be a dangerous strategy. This will result in a large number of people getting ill which in turn would burden the entire health system. More so, the effectiveness of herd immunity also depends upon the population structure of the country.

2.21 SOME IMPORTANT TERMS ASSOCIATED WITH DISEASES

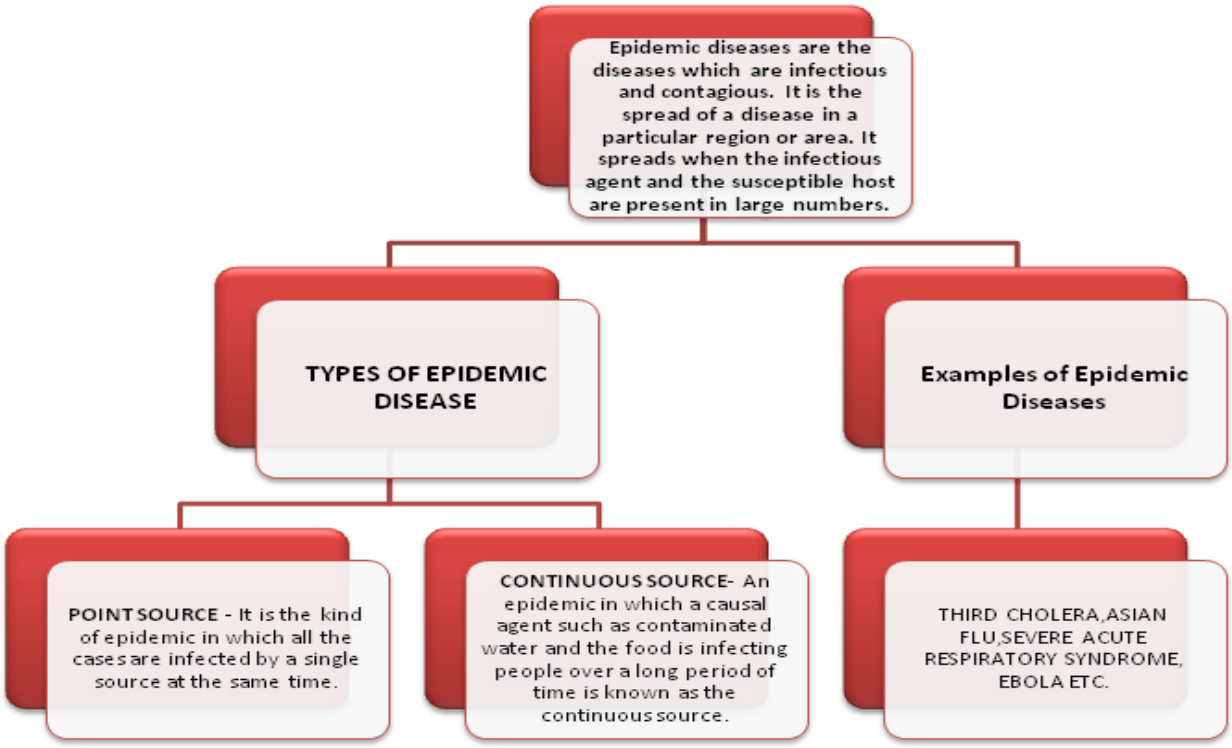
ENDEMIC DISEASE

An endemic disease is the one that is always present in a population, for eg., chicken pox, malaria. Endemic diseases are relatively rare and not as widespread as an epidemic. It is always prevalent in the population that lives in that area. These areas contain viruses, bacteria or parasites which can transmit the diseases to humans. There are two types of endemic diseases:

- **Holoendemic Diseases-** This kind of endemic disease affects mostly children. This infection is highly prevalent in the early years of life. The adult population do not show traces of diseases as much as children do. Malaria is a type of holoendemic disease.

- **Hyperendemic Diseases-** These type of endemic diseases are constantly present at a high rate and are found among all age groups equally

EPIDEMIC DISEASE



PANDEMIC DISEASE -A pandemic disease is an epidemic that has spread across a large area such as multiple continents or worldwide. HIV/AIDS is one of the most destructive pandemic diseases that broke out all over the world. Influenza is another pandemic disease and has occurred more than once. The pandemic is caused by a new infectious agent that has never caused a disease before. It has faced a larger death toll than the epidemic diseases. Antibiotic resistance and increased travel and mobility have increased the risk of diseases among humans.

GENETIC ENGINEERING APPRAISAL COMMITTEE (GEAC)

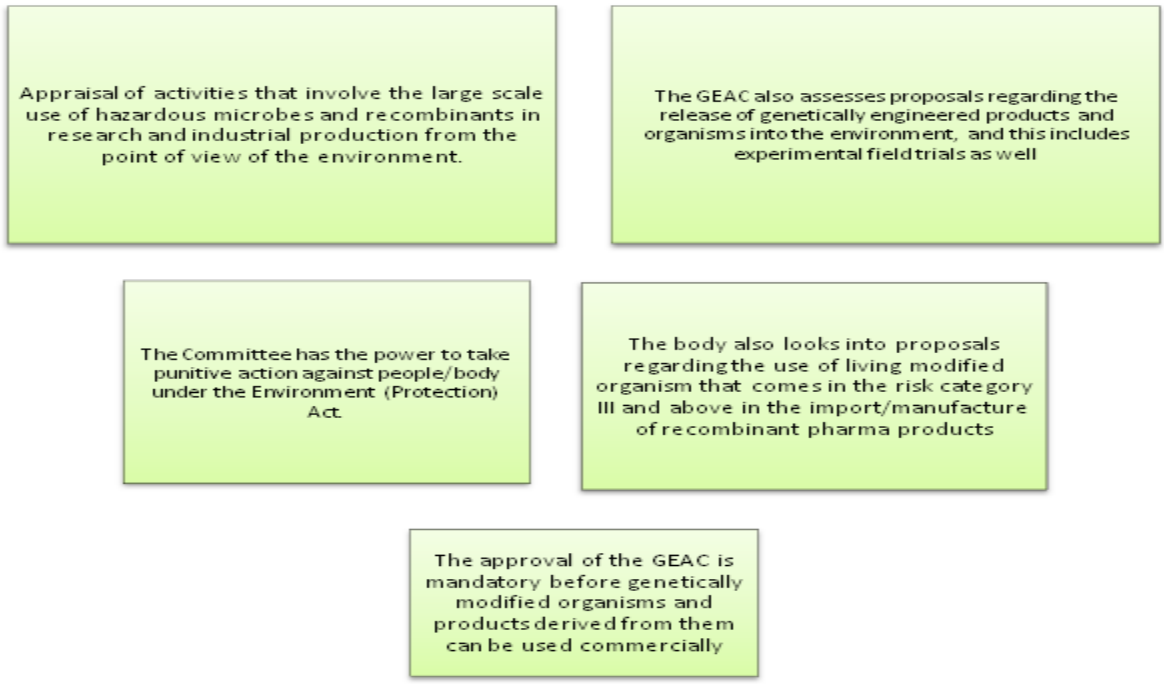
The GEAC is India's apex biotechnology regulatory body.

It is a statutory body constituted under the

'Rules for the Manufacture,Use /Import /Export and Storage of Hazardous Microorganisms/Genetically Engineering Organisms or Cells, 1989' notified under the Environment (Protection) Act, 1986.

- It was formed as the Genetic Engineering Approval Committee and was renamed to its current name in 2010.
- It functions under the Ministry of Environment, Forests & Climate Change.
- The body regulates the use, manufacture, storage, import and export of hazardous microorganisms or genetically-engineered organisms and cells in India.

Functions of GEAC



Composition of GEAC

- The Committee is chaired by the Special Secretary/Additional Secretary of the Ministry of Environment, Forests and Climate Change, GOI.
- A representative of the Department of Biotechnology is a co-chair.

- There are many other members who meet every month to review the applications in the Committee's domain. The members include experts from other ministries as well as institutions such as the ICAR, ICMR, CCMB, etc.

MISCELLANEOUS

2.22 RECENT DEVELOPMENTS RELATED TO BIOTECHNOLOGY

Gene Editing and CRISPR/CaS-9:-

Genome editing, also known as gene editing, is a kind of genetic engineering where the DNA is deleted, inserted or replaced in an organism's genome. generally molecular **scissors'** or **'engineered nucleases',**are used in this technology.

These scissors make double-strand breaks (DSBs) at specific sites in the genome and these breaks are repaired by homologous recombination (HR) or nonhomologous end-joining (NHEJ). This results in targeted mutations or 'edits'.

At present, there are four kinds of engineered nucleases namely, meganucleases, transcription activator-like effector-based nucleases (TALEN), zinc finger nucleases (ZFNs) and **CRISPR/Cas9 systems.**

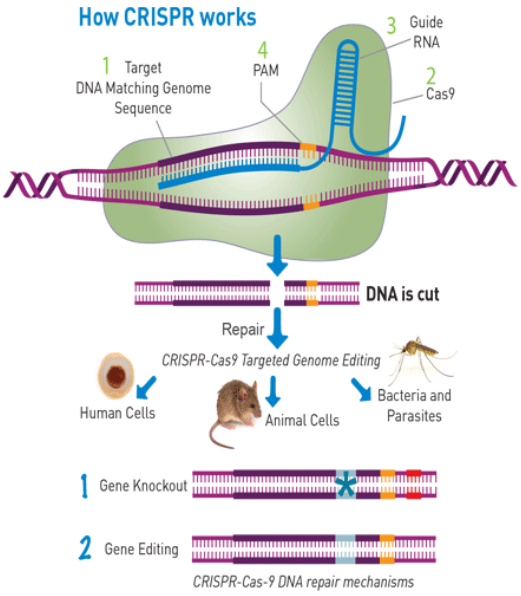


Fig: 1.14 Genome editing

(Image source: science direct)

vii. About CRISPR-CaS 9

It was a scientist named- **He Jiankui , a Chinese, who shocked the scientific community in 2018 after announcing he had successfully altered the genes of twin girls born in November to prevent them from contracting HIV.**

He had "privately" organised a project team that included foreign staff and used "technology of
uncertain safety and effectiveness" for illegal human embryo gene-editing, investigators said. But such gene-editing work is banned in most countries, including China.

Cutting-and-pasting DNA (CRISPR-CAS9)

- The newly developed technology allows scientists to essentially cut-and-paste DNA, which may be used for genetic fixes to cure or treat disease.
- However, there are also safety and ethical concerns about this technology like ;CRISPR allows us to target nearly any genomic location and potentially repair broken genes. It can remove, add or alter specific DNA sequences in the genome of higher organisms.

How does it work?

- Unusual but repeated DNA structures that scientists had been observing for some time were given a name. This name assigned was "Clustered regularly interspaced short palindromic repeats" or CRISPR.
- It was discovered in the year 2012, that CRISPR is a key part of the "immune system".

The CRISPR-Cas9 gene-editing tool thus has two components. They are:

A sequence of short RNA that can bind to a specific target of the DNA	An enzyme called CaS 9 ,which acts as molecular scissors to cut the DNA.

- To edit a gene of interest, the short RNA sequence that perfectly matches with the DNA sequence that has to be edited is introduced. Once it binds to the DNA, the Cas9 enzyme cuts the DNA at the targeted location where the RNA sequence is bound.

- Once the DNA is cut, the natural DNA repair mechanism is utilized to add or remove genetic material or make changes to the DNA.

Advantages of Gene editing	Disadvantages of Gene Editing
● CRISPR could be used to modify disease-causing genes in embryos brought to term, removing the faulty script from the genetic code of that person's future descendants as well. ● Genome editing (Gene editing) could potentially decrease, or even eliminate, the incidence of many serious genetic diseases, reducing human suffering worldwide. ● It might also be possible to install genes that offer lifelong protection against infection. ● CRISPR May Prove Useful in De-Extinction Efforts. For example,Researchers are using the powerfula gene-editing tool to recreate the woolly mammoth. ● CRISPR Could Create New, Healthier Foods: In agricultural crops, Crispr has the potential to impact yield, disease resistance, taste, and other traits. Few experiments have been done. If successful it can help us to eradicate the problem of hunger and malnutrition.	● Making irreversible changes to every cell in the bodies of future children and all their descendants would constitute extraordinarily risky human experimentation. ● Making irreversible changes to every cell in the bodies of future children and all their descendants would constitute extraordinarily risky human experimentation. ● There are issues including off-target mutations (unintentional edits to the genome), persistent editing effects, genetic mechanisms in embryonic and fetal development, and longer-term health and safety consequences. ● There are issues including off-target mutations (unintentional edits to the genome), persistent editing effects, genetic mechanisms in embryonic and fetal development, and longer-term health and safety consequences. ● Altering one gene could have unforeseen and widespread effects on other parts of the genome hence it will become a tool for selecting desired characteristics such as intelligence and attractiveness.

	• It can also be used to eliminate dangerous species of pests and few experiments are being carried out on mosquitoes but eliminating a species, even one that doesn't appear to have much ecological value, could upset the careful balance of ecosystems. That could have disastrous consequences, such as disrupting the food web or increasing the risk that diseases like malaria could be spread by different species entirely.

Current scientific advancements show that CRISPR is not only an extremely versatile technology, it's proving to be precise and increasingly safe to use. But a lot of progress still has to be made; we are only beginning to see the full potential of genome-editing tools like CRISPR-Cas9.

Technological and ethical hurdles still stand between us and a future in which we feed the planet with engineered food, eliminate genetic disorders, or bring extinct animal species back to life.

2.23 MANAV : HUMAN ATLAS PROJECT

Recent times have witnessed an explosion in the amount of biological data generated. There are millions of research articles with pivotal information on human health and disease, spanning from single-molecule resolution to the level of the whole organism. However, this information is scattered in different databases, repositories, and in the text of journal articles.

This makes the seamless extraction of scientific information an extremely challenging and time-consuming (yet incomplete) process. With 100+ databases and millions of data points (combined) from just human cells/tissue and disease, there is a pressing need to collate this information in such a way that users like academic/industrial/clinical researcher as well as

teachers and students can easily access information that is relevant to them from a common and modular platform.

Although there are ambitious ongoing efforts like the Recon X, The Virtual Physiological Human, Human Cell Atlas, none of these projects aim to build the map of the whole human body simultaneously comparing both macro(organ/tissue/cell) and micro (molecular interaction networks) level details.

- Manav-Human Atlas Initiative aims to construct a comprehensive map of the entire human body which will explicitly document macro to micro-level information.
- The project Manav will dramatically accelerate our understanding of the working of the human body and help design better therapeutic targets for treating diseases like cancer, diabetes, and more.
- This project will require understanding, extracting, and collating information from millions of scientific papers that would need a massive investment of time, effort, and manpower.
- The large pool of scientifically literate population in India pursuing a bachelors /masters / Ph.D. is a great resource that will be trained and engaged as part of this project to use the annotation tool being developed to collate, curate, manage and visualize this scientific information.
- This project is funded by the Department of Biotechnology (DBT), Government of India as a collaboration between Persistent Systems, NCCS, and IISER, Pune.

Fig;1.15 Human Atlas Project

(Image source:dbt.gov.in)

2.24 HUMAN GENOME PROJECT

The Human genome project (HGP) was an international scientific research project which was successfully completed in the year 2003 by sequencing the entire human genome of 3.3 billion base pairs. The HGP led to the growth of bioinformatics which is a vast field of research. The successful sequencing of the human genome could solve the mystery of many disorders in humans and gave us a way to cope up with them.

Goals of the human genome project

Goals of the human genome project include:

- Optimization of the data analysis.
- Sequencing the entire genome.
- Identification of the complete human genome.
- Creating genome sequence databases to store the data.
- Taking care of the legal, ethical and social issues that the project may pose.
- Methods of the human genome project
- In this project, two different and significant methods are typically used.

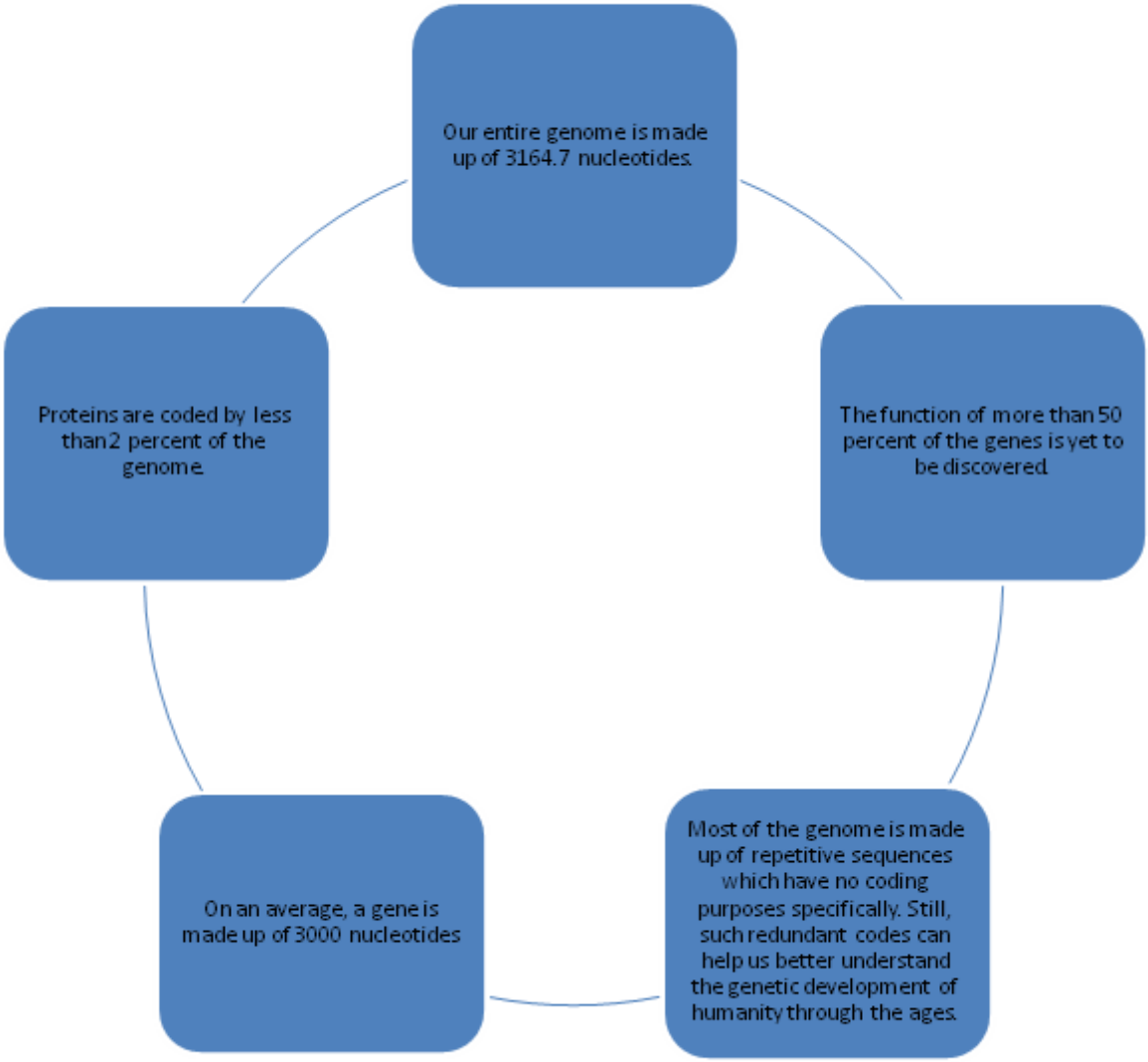
Process and method of Human Genome Project

- Expressed sequence tags wherein the genes were differentiated into the ones forming a part of the genome and the others which expressed RNAs.
- Sequence Annotation wherein the entire genome was first sequenced and the functional tags were assigned later.

Process

- The process of the human genome project
- The complete gene set was isolated from a cell.
- It was then split into small fragments.
- This DNA structure was then amplified with the help of a vector which mostly was BAC (Bacterial artificial chromosomes) and YAC (Yeast artificial chromosomes).
- The smaller fragments were then sequenced using DNA sequencers.
- On the basis of overlapping regions, the sequences were then arranged.
- All the information of this genome sequence was then stored in a computer-based program.
- This way the entire genome was sequenced and stored as a genome database in computers. Genome mapping was the next goal which was achieved with the help of microsatellites (repetitive DNA sequences).

Features of the project



2.25 APPLICATIONS OF HUMAN GENOME PROJECT

As the goals of the human genome project were achieved, it led to great advancement in research. Today, if any disease arises due to some alteration in a certain gene, then it could be

traced and compared to the genome database that we already have. In this way, a more rational step could be taken to deal with the problem and can be fixed with more ease.

Human Genome Project (write)

The Genome Project - Write (also known as GP-Write) is a large-scale collaborative research project an extension of Human Genome Project, that focuses on the development of technologies for the synthesis and testing of genomes of many different species of microbes, plants, and animals, including the human genome in a sub-project known as Human **Genome Project-Write (HGP-Write)**

Formally announced on 2 June 2016, the project leverages two decades of work on synthetic biology and artificial gene synthesis. The newly created HGP-Write project will be managed by the Center of Excellence for Engineering Biology, an American nonprofit organization. Researchers expect that the ability to artificially synthesize large portions of many genomes will result in many scientific and medical advances

A complete haploid copy of the human genome consists of at least three billion DNA nucleotide base pairs, which have been described in the **Human Genome Project - Read** program (95% completed as of 2004). Among the many goals of GP-Write is the making of cell lines resistant to all viruses and synthesis assembly lines to test variants of unknown significance that arise in research and diagnostic sequencing of human genomes (which has been exponentially improving in cost, quality, and interpretation).

2.26 BIOLOGICAL PESTICIDES

Biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals. For example, canola oil and baking soda have pesticidal applications and are considered biopesticides. This process is also referred to a biological control. The biological application is mainly introduced to reduce the population of a pest and to produce pest-free yields. It is a self-sustaining and long-term treatment method, for managing invasive plants. The living organism applied in this system is used to suppress a weed infestation and to control pests including insects, pathogens, and grazing animals.

The natural enemies like parasitism, predation, and other mechanisms for controlling the plant pests are referred to as a biocontrol agent. They play an important role in controlling

plant pests like nematodes, weeds, insects, and mites. The biological control agent helps in maintaining and balancing the plant species along with their natural enemies.

Agent	Target pest or weed
Microbial insecticides	
Bacteria	
Bacillus thuringiensis	Lepidoptera (moths/butterflies) Diptera (flies) Coleoptera (beetles)
Fungi	
Verticillium lecanii	Aphids and whiteflies
Metarhizium anisopliae	Spittlebugs
Metarhizium flavoviride	Locusts and grasshoppers
Beauveria bassiana	Colorado beetle
Virus	
Nuclear polyhedrosis	Various
Virus	
Mycoherbicides	
Colletotrichum gloeosporioides	Northern jointvetch (*Aeschynomene virginiana*)
Colletotrichum orbiculare	Round-leaved mallow (*Malva pusilla*)
Phytophthora orbiculare	Milkweed vine (*Morrenia odorata*)
Alternaria cassiae	Sicklepod (*Cassia obtusifolia*)
Puccinia chondrilina	Skeleton weed (*Chondrilla juncea*)

Fig: 1.16 Examples of Biocontrol Agents

(imagesource: agriculture inindia.net)

Types of Biocontrol Agents

Biological control can be categorized into 2 types, namely inundated and classical.

Inundative BioControl	Classical biocontrol
This approach uses pathogens, where they are used to apply on a target weed at a very high rate in an aspect that is similar to herbicide application. The most common pathogens used in inundative biological control include nematodes and nuts. This approach does not prevent the invasive plant from implementing at a later date	It uses agent populations that would waver in a natural prey and predator relationship. This method adopts natural predators of the invasive plant to create an eternal relationship between a plant and biological control animals.

List of Biocontrol Agents:

Predators: They are mainly free-living species that consume prey in large numbers during their lifespan. Since the majority of insects constitute crop pests. Some of the predators include Lacewings, Spiders, Flies, Beetles, and dragonflies.

Pathogens: Virus, Bacteria, and fungi are relatively pathogenic micro-organisms that are host specifics or kill their host. Some of the microbial diseases occur naturally but they are used as biological pesticides.

Bacteria: Bacteria belonging to the coccobacillus group are more pathogenic to insects. They are used for biological control. They infect the digestive tract of insects thus limiting the options for controlling insects with sucking mouthparts namely scale insects and aphids.

Viruses: The use of insect virus as a controlling agent is still in inception. Since they are host specific, they turn out to have good potential as biocontrol agents.

Fungi: The fungi Entomophaga is effective against pests namely green peach aphid.

Parasitoids: They lay eggs in the body of the host (insect), eventually killing the host. It is later used as a source of food for the developing larva. It is one of the most widely used biological control agents.

Merits

- The biological control agents are environmentally friendly and cause no side effects.
- Less cost compared to other Agrochemicals – pesticides and insecticides.
- Easily available, easy to use and is effective throughout the season.
- Helps in reducing the use of chemicals and other pesticides.

Demerits

- It affects the product quality.
- Pest is not completely destroyed by these biological control agents.
- It is effective only for large scale

2.27 DNA FINGERPRINTING

It is defined as**" a technique that shows the genetic makeup of living things. It is a method of finding the difference between the satellite DNA regions in the genome**".

Satellite DNA regions are stretches of repetitive DNA which do not code for any specific protein. These non-coding sequences form a major chunk of the DNA profile of humans. They depict a high level of polymorphism and are the basis of DNA fingerprinting. These genes show a high level of polymorphism in all kinds of tissues as a result of which they prove to be very useful in forensic studies.

Any piece of DNA sample found at a crime scene can be analyzed for the level of polymorphism in the non-coding repetitive sequences. After the DNA profile is traced, it becomes easier to find the criminal by performing the DNA fingerprinting for the suspects.

Apart from crime scenes, Fingerprinting applications also prove useful in finding the parents of an unclaimed baby by conducting a paternity test on a DNA sample from the baby.

DNA Fingerprinting Steps

Alec Jeffreys developed this technique in which he used satellite DNAs also called VNTRs (Variable Number of Tandem Repeats) as a probe because it showed the high level of polymorphism.

Isolating the DNA.

↓

Digesting the DNA with the help of restriction endonuclease enzymes.

↓

Separating the digested fragments as per the fragment size by the process of electrophoresis.

↓

Blotting the separated fragments onto synthetic membranes like nylon.

↓

Hybridising the fragments using labelled VNTR probes.

↓

Analysing the hybrid fragments using autoradiography.

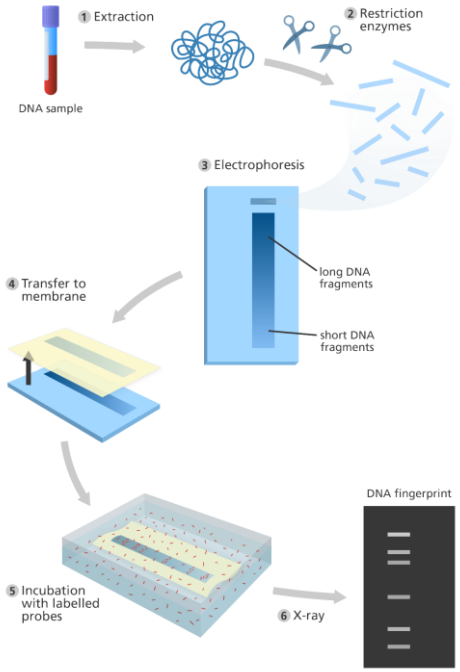


Fig: 1.17 Steps of DNA fingerprinting

(Image source: yourgenome)

2.28 APPLICATIONS OF DNA FINGERPRINTING

As discussed earlier the technique of fingerprinting is used for DNA analysis in forensic tests and paternity tests. Apart from these two fields, it is also used in determining the frequency of a particular gene in a population which gives rise to diversity. In case of the change in gene frequency or genetic drift, Fingerprinting can be used to trace the role of this change in evolution.

- Paternity and maternity
- Criminal identification and forensics
- Personal identification

2.29 STEM CELLS

Stem cells are" special human cells that can develop into many different types of cells, from muscle cells to brain cells."

Stem cells also have the ability to repair the damaged cells. These cells have strong healing power. They can evolve into any type of cell.

Research is going on and it is believed that stem cell therapies can cure ailments like paralysis and Alzheimer's as well.

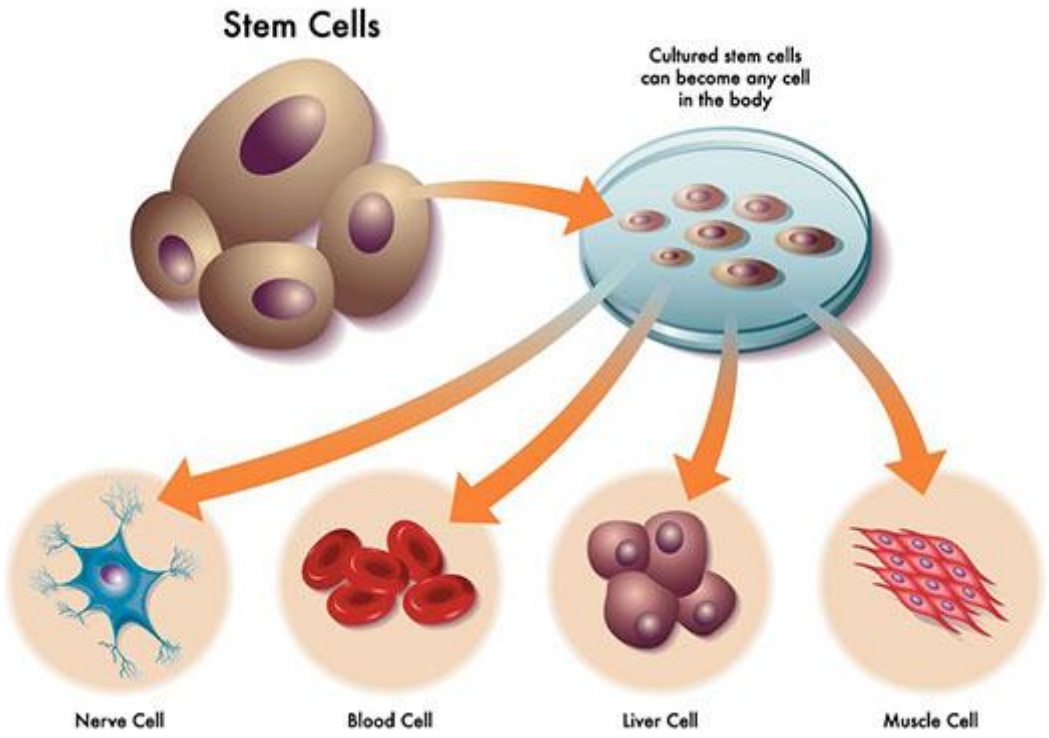


Fig:1.18 Stem cells

(Image source: Byjus.com)

Types of Stem Cells

Embryonic Stem Cells

The fertilized egg begins to divide immediately. All the cells in the young embryo are totipotent cells. These cells form a hollow structure within a few days. Cells in one region

group together to form the inner cell mass. This contains pluripotent cells that make up the developing foetus.

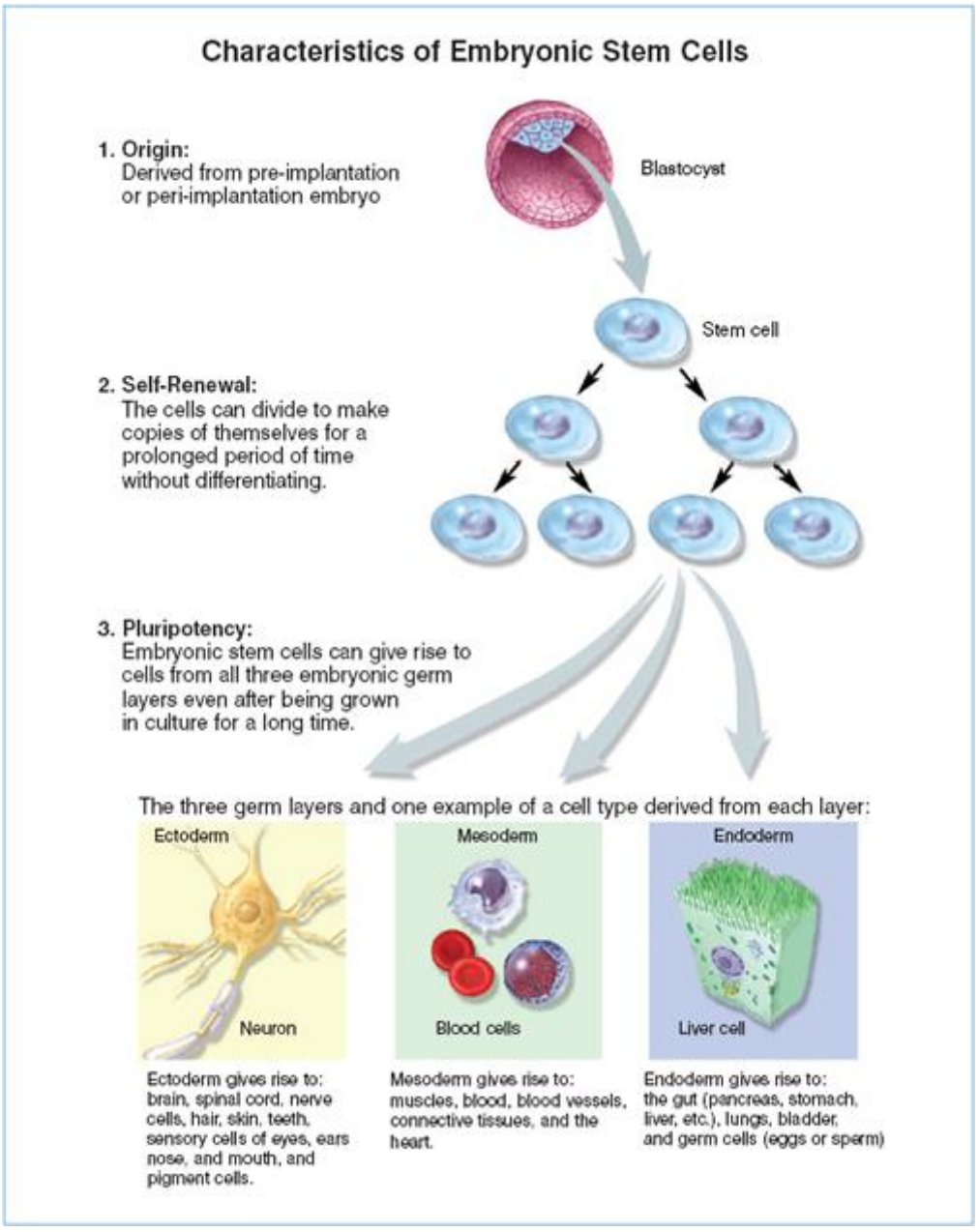


Fig :1.19 embryonic stem cells

(*Image source: Byjus.com)*

The embryonic stem cells can be further classified as:

Totipotent Stem Cells	**Pluripotent Stem Cells**	**Multipotent Stem Cells**	**Oligopotent Stem Cells**

These can differentiate into all possible types of stem cells	These are the cells from early embryos and can differentiate into any cell type.	These differentiate into a closely related cell type. For eg., the hematopoietic stem cells differentiate into red blood cells and white blood cells.	**Examples of oligopotent cells include**Adult lymphoid cells(any of the cells responsible for the production of immunity mediated by cells or antibodies and including lymphocytes, lymphoblasts, and plasma cells.) or myeloid cell that can differentiate into any of the blood stem cells found in the lymphatic system. They can differentiate into a few different types of cells.

Note:- Apart from above there are Unipotent Stem Cells: They can produce cells only of their own type. Since they have the ability to renew themselves, they are known as unipotent stem cells. For eg., Muscle stem cells

Adult Stem Cells:

These stem cells are obtained from developed organs and tissues. They can repair and replace the damaged tissues in the region where they are located. For eg., hematopoietic stem cells are found in the bone marrow. These stem cells are used in bone marrow transplants to treat specific types of cancers.

Induced Pluripotent Stem Cells:

These cells have been tested and arranged by converting tissue-specific cells into embryonic cells in the lab. These cells are accepted as an important tool to learn about normal

development, onset and progression of the disease and also helpful in testing various drugs. These stem cells share the same characteristics as embryonic cells do. They also have the potential to give rise to all the different types of cells in the human body.

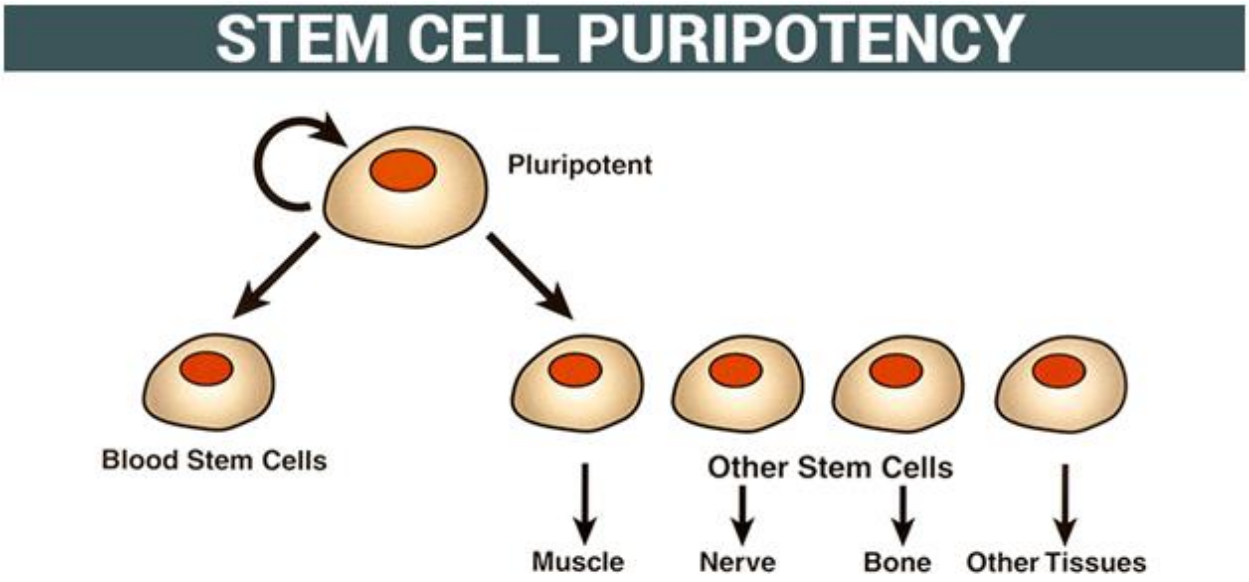


Fig: 1.20 Induced Pluripotent Stem Cells

(Image source: Byjus)

Mesenchymal Stem Cells:

These cells are mainly formed from the connective tissues surrounding other tissues and organs known as stroma. These mesenchymal stem cells are accurately called stromal cells. The first mesenchymal stem cells were found in the bone marrow that are capable of developing bones, fat cells, and cartilage.

There are different mesenchymal stem cells that are used to treat various diseases as they have been developed from different tissues of the human body. The characteristics of mesenchymal stem cells depend on the organ from where they originate.

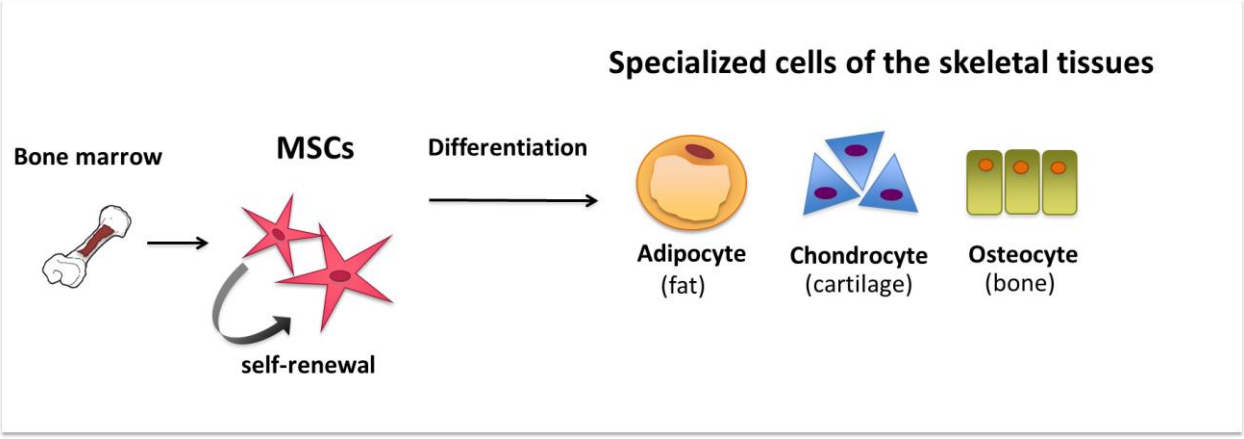


Fig:1.21 Mesenchymal stem cells

(Image source: Eurocell)

Applications of Stem Cells

Following are the important applications of stem cells:-

Tissue Regeneration	**Cardiovascular diseases**	**Brain diseases treatment**	**Treatment of Blood Diseases**
This is the most important application of stem cells. The stem cells can be used to grow a specific type of tissue or organ. This can be helpful in kidney and liver transplants. The doctors have already used the stem cells from beneath the epidermis to develop skin tissue that can repair severe burns or other injuries by	A team of researchers have developed blood vessels in mice using human stem cells. Within two weeks of implantation, the blood vessels formed their network and were as efficient as the natural vessels.	Stem cells can also treat diseases such as Parkinson's disease and Alzheimer's. These can help to replenish the damaged brain cells. The researchers have tried to differentiate embryonic stem cells into these types of cells. Therefore, it is possible to treat the diseases.	The adult hematopoietic stem cells are used to treat cancers, sickle cell anaemia, and other immunodeficiency diseases. These stem cells can be used to produce red blood cells and white blood cells in the body.

tissue grafting.			

Sources of Stem Cells

- Stem Cells originate from different parts of the body. Adult stem cells can be found in specific tissues in the human body. Matured cells are specialized to conduct various functions. Generally, these cells can develop the kind of cells found in tissues where they reside.
- Embryonic Stem Cells are derived from 5-day old blastocysts that develop into embryos and are pluripotent. These cells can develop any type of cell and tissue in the body. These cells have the potential to regenerate all the cells and tissues that have been lost because of any kind of injury or disease.

Stem Cells Research in India

- There is no law to regulate the use of stem cells in India. **The Indian Council of Medical Research (ICMR)** has issued guidelines that recognize stem cell therapies only for certain treatments and observes that other types of treatments are unproven and should not be offered as therapy. The Health Ministry has sought to change the rules by amending the law.
- The law that regulates the use and approval of drugs in India is the Drugs and Cosmetics Act.
- At present stem cells are not classified as drugs in India. **If the Drugs and Cosmetics Act is amended by the Government then stem cells will be classified as Drugs and it will come under the jurisdiction of 'Drugs Controller General of India.**' However in the proposed amendment stem cells that are 'minimally manipulated' are excluded from the definition of a new drug.
- Stem cells are minimally manipulated, meaning they are subjected to minimal manipulation when stem cells are taken from an individual, subjected to minor procedures like rinsing, cleaning, and resizing and do not undergo any other processing steps that may alter their function before being implanted into the same individual.
- India carries out stem cell research. The government of India has been supporting the research through funding agencies like the Department of Biotechnology (DBT), Department of Science and Technology (DST), Indian Council of Medical Research

(ICMR). This has resulted in the establishment of the state of the art infrastructure at over 40 premier health research and education institutions.

- **The guidelines are given in the National Guidelines for Stem Cell Research (NASCAR-2013).**

2.30 BIOSENSORS

Biosensors are nowadays ubiquitous in biomedical diagnosis as well as a wide range of other areas such as point-of-care monitoring of treatment and disease progression, environmental monitoring, food control, drug discovery, forensics and biomedical research. A wide range of techniques can be used for the development of biosensors. Their coupling with high-affinity biomolecules allows the sensitive and selective detection of a range of analytes.

Characteristics of Biosensors:

A biosensor is a device that measures biological or chemical reactions by generating signals proportional to the concentration of an analyte in the reaction. Biosensors are employed in applications such as disease monitoring, drug discovery, and detection of pollutants, disease-causing microorganisms, and markers that are indicators of disease in bodily fluids (blood, urine, saliva, sweat).

A typical biosensor consists of the following components:

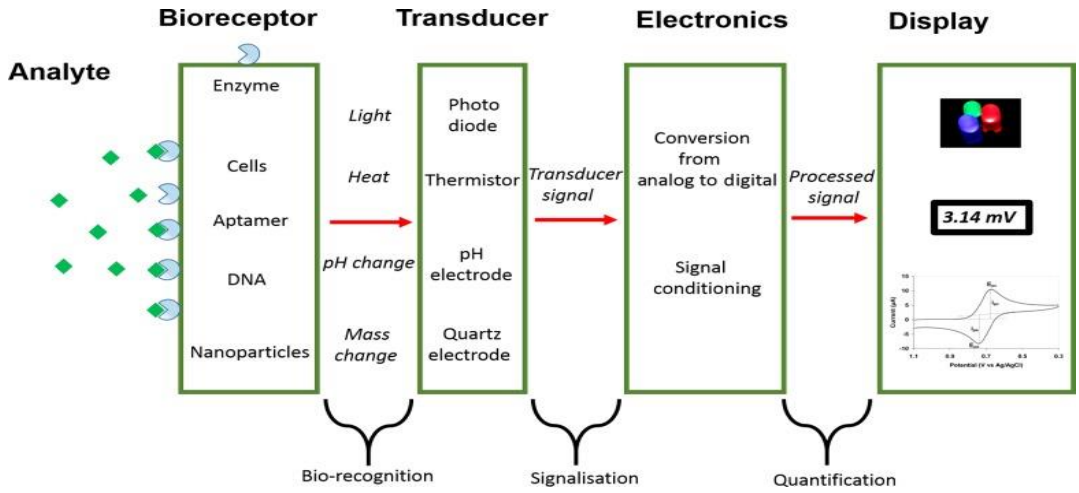


Fig:1.22 Biosensor

(Image Source: https://www.ncbi.nlm.nih.gov/)

- **Analyte**: A substance of interest that needs detection. For instance, glucose is an 'analyte' in a biosensor designed to detect glucose.

- **Bioreceptor**: A molecule that specifically recognizes the analyte is known as a bioreceptor. Enzymes, cells, aptamers, deoxyribonucleic acid (DNA), and antibodies are some examples of receptors. The process of signal generation (in the form of light, heat, pH, charge or mass change, etc.) upon the interaction of the bioreceptor with the analyte is termed bio-recognition.
- **Transducer**: The transducer is an element that converts one form of energy into another. In a biosensor, the role of the transducer is to convert the bio-recognition event into a measurable signal. This process of energy conversion is known as signalization. Most transducers produce either optical or electrical signals that are usually proportional to the amount of analyte–bioreceptor interactions.
- **Electronics**: This is the part of a biosensor that processes the transducer signal and prepares it for display. It consists of complex electronic circuitry that performs signal conditioning such as amplification and conversion of signals from analog into the digital form. The processed signals are then quantified by the display unit of the biosensor.
- **Display**: The display consists of a user interpretation system such as the liquid crystal display of a computer or a direct printer that generates numbers or curves understandable by the user. This part often consists of a combination of hardware and software that generates results of the biosensor in a user-friendly manner. The output signal on display can be numeric, graphic, tabular, or an image, depending on the requirements of the end-user.

Applications of Biosensors

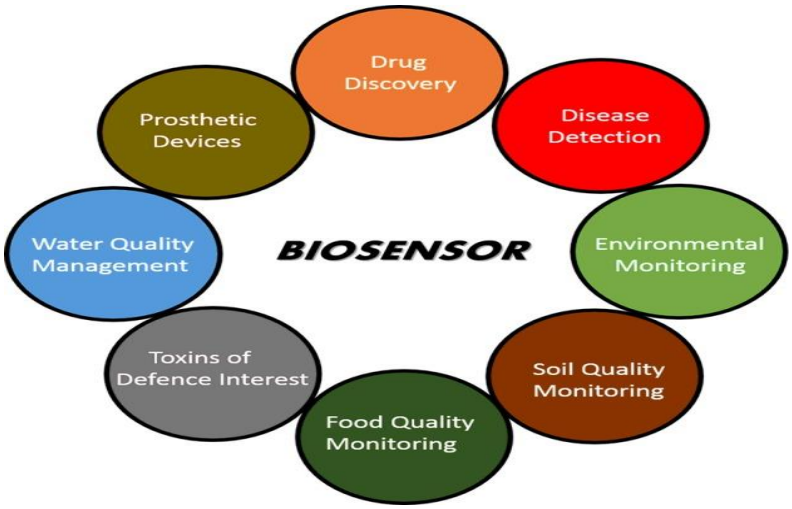


Fig1.23 Applications of Biosensors

(Image source: https://www.ncbi.nlm.nih.gov/)

2.31 BIOGRIDS

BioGRID stands for Biological General Repository for Interaction Datasets. It is an open-access database for the purpose of curation and archival storage of genetic, protein and chemical interactions related to all major model organism species and humans. The Biological General Repository for Interaction Datasets (BioGRID) was created in 2003, originally called the General Repository for Interaction Datasets (GRID, by Mike Tyers, Bobby-Joe Breitkreutz, and Chris Stark at the Lunenfeld-Tanenbaum Research Institute at Mount Sinai Hospital.

It strives to provide a comprehensive curated resource for all major model organism species while attempting to remove redundancy to create a single mapping of data. Users of The BioGRID can search for their protein or publication of interest and retrieve annotation, as well as curated data as reported, by the primary literature and compiled by in house large-scale curation efforts. The BioGRID is hosted in Toronto, Ontario, Canada and Dallas, Texas, United States and is partnered with the Saccharomyces Genome Database. The BioGRID is funded by the BBSRC, NIH, and CIHR. BioGRID is a member of the International Molecular Exchange Consortium (IMEx).