

Biotechnology and its applications

- Biotechnology has varied applications,
Some of which include :-

- 1) Therapeutics (healing process)
- 2) Diagnostics
- 3) Genetically modified crops for agriculture
- 4) Processed food
- 5) Bioremediation
- 6) waste treatment
- 7) Energy production.

These [★] Applications of Biotechnology
in Agriculture and Medicine.

There are three critical research areas
of biotechnology.

- 1) Providing best Catalyst as improved
organisms.
(usually, a microbe or
pure enzyme)

- 2) Creating optimal conditions by engineering

for a catalyst to act.

- 3) Downstream Processing technologies to purify the proteins / organic compound. ★

BIOTECHNOLOGICAL APPLICATIONS IN AGRICULTURE

Food production can be increased by applying biotechnology by the following ways.

- a) Agrochemical-based agriculture.
- b) Organic agriculture.
- c) Genetically engineered crop-based agriculture.

Green Revolution

Succeeded in increasing food supply because of -

- i. use of improved crop varieties.
- ii. use of agrochemicals (fertilisers & Pesticides)
- iii. use of better management practices.

★ Agrochemicals are expensive for farmers in developing countries and also have harmful effects on environment. Therefore genetically modified crops were developed.

Genetically modified organism (GMOs)

★ Plants, bacteria, fungi and animals whose genes have been altered by manipulation. (GMOs)

- These are also called transgenic organisms.
- They contain and express one or more foreign gene called transgene.
- GM plants are useful in many ways.

Genetic modification of crops have results to changes the phenotypic expression of plant.

- ① Increased tolerance against abiotic stresses.
(cold, drought, salt heat)
- ② Reduced reliance on chemical pesticides.
(Pest-resistant crop)
- ③ Reduced post-harvest losses.
- ④ Increased efficiency of minerals used by plants (this prevents early exhaustion of fertility of soil)



- ③ Enhanced nutritional value of food e.g. Vitamin 'A' enriched rice (Golden rice)
- ④ Creation of tailor made plants to supply alternative resources ~~and~~ such as starches, fuels and pharmaceuticals to industries.

Biopesticides

An application of biotechnology in agriculture is the production of pest-resistant plants which could decrease the amount of pesticides being used.

1. Bt Cotton

- Some strains Bacillus thuringiensis produce protein crystals during a particular phase of their growth.
- The crystals contain a toxic insecticidal protein that kill certain insects such as lepidoterans (tobacco budworm, armyworm), coleopterans (beetles) and dipterans (flies, mosquitoes).
- ★ The toxin does not kill the Bacillus because the Bt toxin protein exists as inactive protoxins but once the insect ingests the inactive toxin, it is converted into an active form of toxin due to the alkaline pH of the gut which solubilize the crystals.



— The activated toxin binds to the surface of mid gut epithelial cells and create pores that cause cell swelling and lysis cause that cause cell swelling and lysis and cause death of the insect.

— The toxin is coded by a gene named cry.



— Bt cotton tobacco was first cultured to kill hornworm (*Manduca sexta*)

For e.g.

i. cry IAc and cry IIAb control cotton bollworms.

ii. cry IAb control Corn borer.

iii. cry IIIAb control Colorado potato beetle.

iv. cry IIIBb control Corn root worm.

— Specific Bt toxin genes were isolated from *Bacillus thuringiensis* based on the crop and the targeted pest which is then incorporated into the several crop plants.

2. Pest - Resistant Plant

— A nematode Meloidogyne incognita infects



the root of tobacco plants which reduces the production of tobacco.

- It can be prevented by using RNA interference (RNAi) process which is checked by silencing of specific mRNA due to complementary dsRNA.
- dsRNA binds and prevents translation of the mRNA (Silencing).
- By using Agrobacterium vector, nematode-specific genes were introduced into the host plants which produce both Sense and anti-Sense RNA in the host cells.
- These two RNAs are Complementary to each other and form a double-stranded RNA (dsRNA) that initiates RNAi and hence silence the specific mRNA of the nematode.
- The parasites cannot survive in the transgenic host.
- So protects the plants from pests.

Biotechnological Applications In Medicine

- The recombinant DNA technology is used for production of therapeutic drugs which are safe and effective.

- It avoids unwanted immunological response commonly observed with similar products isolated from non-human resources.
- About 30 recombinant therapeutics have been approved for human use in the world.
- 12 are marketed in India

Genetically Engineered Insulin

- Insulin contains two short polypeptide chains - Chain A and chain B linked by disulphide bridges.
- In mammals, Insulin is synthesized as a pro-hormone (that needs to be processed to become mature and functional hormone). It contains an extra stretch called C-peptide.
- C-peptide is absent in mature Insulin and is removed during maturation into insulin.
- Earlier, Insulin was extracted from Pancreas of Slaughtered Cattle and pigs but some patients began developing allergies.

- Production of insulin by or DNA techniques was achieved by an American Company Eli Lilly in 1983. It prepared two DNA sequences corresponding to A and B chains of human insulin and introduced them in Plasmid of E. coli for production.
- The A and B chains produced (separately) extracted and combined by creating disulphide bonds to form human insulin called Humulin.

Recombinant Vaccine

- * The vaccine produced through genetic engineering methods are called recombinant vaccines. Or Second Generation Vaccine.
- Recombinant hepatitis-B Vaccine and polio vaccine are example of recombinant DNA vaccine.

Stem Cell Technology

- used for treatment of malignant and non-malignant disease by using stem cells.
- Stem cells are undifferentiated biological cells. These can differentiate into specialized cells and can divide to produce more stem cells.

— These cells are found in multicellular organisms.

— Mainly of 2 types

① embryonic stem cell → Isolated from the inner cell mass of blastocysts.

② Adult stem cell → exist throughout the body after embryonic development and found in different type of tissues (Brain)

— Adult Stem cells are used in medical therapies, e.g. in bone marrow transplantation

— Stem cells can also be taken from umbilical cord blood just after birth.

Gene Therapy

— Gene therapy is a collection of methods that allows correction of gene defects diag diagnosed in a child or embryo.

— By insertion of normal genes, the defective mutant allele of the genes are replaced and non-functional gene is compensated

- For the first time in 1990, M. Blaise and W.F. Anderson of National Institute of Health attempted gene therapy on a 4 year old girl with Adenosine Deaminase (ADA) deficiency.
- ADA is caused due to deletion of gene for adenosine deaminase.
- In some cases, it can be cured by bone marrow transplantation and Enzyme replacement therapy but it is not fully curative.

STEPS

- Lymphocytes from patient's blood were grown in culture and functional ADA, cDNA was introduced in these lymphocytes using a retroviral vector.
- The lymphocytes were transferred into the patient's body. Periodic infusion of such genetically engineered lymphocytes is done because these cells are mortal.
- ★ For Permanent cure - Gene isolated from the bone marrow cells producing ADA, at early embryonic stage can be a possible cure.

- Other disease like Cystic fibrosis, haemophilia, Cancer, Parkinson's etc are also treated by gene therapy.

Molecular Diagnosis

- Early detection of a disease is not possible by conventional diagnosis methods.
- Some techniques used for early diagnosis are —

(a) Polymerase chain reaction

* — Low concentration of the pathogen in the body does not allow its detection.

- The nuclear acid of the pathogen (bacteria or virus) is amplified by PCR for its detection.

- It is being used for detection of HIV in suspected AIDS patients and genetic mutation in suspected cancer patients.

b) Recombinant DNA technology

- A single stranded DNA or RNA tagged with a radioactive molecule called probe.
- In the method, a probe is allowed to hybridise to its complementary DNA in the clone of cells.
- The cells are then detected by autoradiography.
- The cells with mutated gene will not be observed on the photographic film because the probe was not complementary to the mutated gene.

a) Enzyme linked Immune-sorbent assay (ELISA)

- It is based on the principle of antigen-antibody interaction.
- Either the presence of antigens (Protein, Glycoprotein etc) are detected or the antibodies produced against the pathogens are detected.

Transgenic Animals

Animals whose DNA is manipulated to possess and express an extra gene are known as transgenic animals.

e.g. Transgenic rats, rabbits, pigs, sheep and cows have been produced.

★ Following are the common reasons for developing transgenic animals.

1) Study of normal physiology and development

- Useful to study gene regulation, their effect on the normal functions of the body and its development.

- e.g. Study of complex growth factors like - Insulin - like growth factor.

2) Study of disease

- Study of genes which are responsible for disease in human and their treatment.



- Transgenic models have been developed for many human disease like Cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's disease.

3) Biological Products

- Useful biological products can be produced by introducing into transgenic animals, the portion of DNA (or gene) which codes
- For a particular product.
- e.g. Human protein (α -1 antitrypsin) is used to treat emphysema (breathing problem)
- In 1997, the first transgenic cow Rosie produced human protein-enriched milk (2.4 g/L)
- The milk contained the human alpha-lactalbumin and was more nutritionally balanced for human babies than natural cow milk.

4) Vaccine Safety

- Transgenic mice are developed to test safety of vaccines, before being used on humans.
- e.g. - Polio vaccines.

5) Chemical Safety testing

- It is also known as toxicity or Safety testing.

- Transgenic animals are made that carry the genes, which make them more sensitive to toxic substances than the non-transgenic animals.

- They are then exposed to toxic substances and effects are studied.

- This allows us to obtain results in less time.

ETHICAL ISSUES

- Genetic modification of organisms can have unpredictable results & when such organisms are introduced into the ecosystem, the Indian Government has set up organizations such as GEAC (Genetic Engineering Approval Committee) to make decisions regarding the validity of GM research and the safety of introducing GM organisms for public service.

- There is a need for some ethical standards to evaluate our actions. These sets of standards that are used to regulate our activities in relation to biological world are called bioethics.

Patent

- A patent is a set of exclusive rights granted by a state to an inventor or their assignee for a limited period of time in exchange for public disclosure of an invention.
- Patents satisfy three criteria - novelty, non-obviousness, utility.

Bio piracy

- Bio piracy is defined as the use of bioresources by multinational companies and other organisations without proper authorization from the countries and concerned people, without compensatory payment.
- Generally, financially rich nations are poor in bio diversity and traditional knowledge, while developing under developed nations are rich in bio diversity and traditional knowledge related to bioresources.

- Traditional knowledge related to bioresources can be exploited to develop modern applications and are used to save time efforts and expenditure during their commercialization.

- Some Nations are developing law to prevent such unauthorised exploitation of their bioresources and traditional knowledge.

- Indian Parliament has recently cleared the Second amendment of the Indian Patents Bill. It takes consideration of such issues including patent terms, emergency provisions, research and development initiative.

Controversies In India Regarding Patent and Biopiracy

Basmati Rice

An American Company got patent rights on Basmati rice but the variety of basmati had actually been derived from Indian farmer's varieties.

Turmeric and Neem

In May 1995, the US Patent office granted to the University of Mississippi Medical Center a patent for 'Use of Turmeric in Wound Healing'.

In 1966, another patent was granted to the R. Grace & Co., by the European Patent Office, Munich for fungicidal uses of neem. Thus, if we do not pay attention to our patent applications, our rich legacy is shared by other countries & individuals.