Biotechnology and its Applications

Genetically Engineered Crops

- Genetically engineered crops have desirable genes (as of insect/pest resistance, giving better yield) incorporated in them.
- Genetically modified crops have
  - more tolerance to abiotic stresses such as cold, drought, salinity, heat, etc.
  - insect/pest resistance
  - reduced post-harvest losses
  - efficient mineral usage by plants
  - enhanced nutritional value (e.g., Vitamin A rich rice)

Bt Cotton

- Bacillus thuringiensis is a bacterium that produces proteins to kill certain insects such as lepidopterans (armyworm), coleopterans(beetles), and dipterans (flies/ mosquitoes). B. thuringiensis produces a protein crystal containing a toxic protein (inactivated state).
- Inactivated toxin Activated toxin (gut of insect)
- Activated toxin binds to the epithelial cells in the midgut of the insect and creates pores that cause lysis and swelling and eventually death of the insect.
- This toxin is encoded by a gene called Cryin the bacterium. Genes encoded by Cry IAc and Cry II Ab control cotton bollworms and those encoded by Cry IAb control corn borer.
- Cry genes are introduced into the cotton plants to produce Bt cotton, which is an insect resistant variety of cotton.

RNA Interference (RNAi)

- RNAi is a method adopted to prevent infestation of roots of tobacco plants by a nematode Meloidogyne incognita.
- In RNAi, a complementary RNA binds to mRNA to form a ds RNA, which cannot translate and hence, its expression is blocked
(Silencing).
- This complementary mRNA may come from
    - infection by RNA viruses
    - transposons (mobile genetic elements)
- RNAi exists naturally in eukaryotes as a method of cellular defence.
- Nematode specific genes (DNA) were introduced in the host plant.
- The introduced DNA forms both sense and anti-sense RNA.
- Two strands being complementary to each other bend and form ds RNA, leading to RNAi.
- mRNA of nematodes is silenced and the parasite cannot survive in the transgenic host.

Applications of Biotechnology in Medicine

Recombinant Therapeutics

- With the help of RDT, mass production of efficient therapeutic drugs can be accomplished.
- These are safe and do not induce unwanted immunological responses.

Genetically Engineered Insulin

- Insulin is in great demand due to an increase in the number of patients with adult onset diabetes.
- Insulin extracted from animal sources (example, slaughtered cattle and pigs) induce allergy in humans.
- Insulin as a pro-enzyme consists of 3 peptide chains – A, B, and C.
- Pro-enzyme insulin Mature insulin
- Mature insulin consists of only two peptide chains – A and B. Both these chains were separately isolated and introduced in plasmids of E. coli to produce insulin chains.
- Separately produced chains A and B were extracted and combined by creating a disulphide bond to form mature human insulin.

Gene Therapy

- Gene therapy is an attempt to deal with genetic or congenital diseases.
- This aims at correction of a genetic defect by delivery of a normal gene into an individual or embryo to take over or compensate for the function for a non-functional gene.
- The first disease to have a gene therapy is ADA (Adenosine deaminase) deficiency. In this, the gene coding for enzyme ADA gets deleted leading to deficiency of ADA and problems in the immune system.
- ADA deficiency can also be treated with:
    - Bone marrow transplantation
    - Enzyme replacement therapy
- Gene therapy for ADA deficiency:

- Lymphocytes isolated from a patient's blood are cultured in vitro.
- Functional ADA cDNA are then introduced into the cultured lymphocytes.
- These lymphocytes are returned back to the patient' s body.

- Lymphocytes are not immortal. Therefore, repeated infusion of genetically engineered lymphocytes is required.
- Permanent cure – Introduction of gene isolated from bone marrow cells producing ADA into cells at early embryonic stages

Molecular Diagnosis

- Recombinant DNA technologies, PCR, ELISA (enzyme linked immunosorbent assay) are some of the technologies of molecular diagnosis.
- Early diagnosis of bacteria and viruses in the body, when the concentration is extremely low, can be done by PCR since it amplifies the DNA several fold.
- PCR is used to detect HIV virus in suspected AIDS patients and mutations in genes in suspected cancer patients.
- ELISA is based on antigen antibody interactions. In the presence of an antigen, the antibody produced against it can be detected.
- Hybridisation with a radioactive probe – In this approach, the gene is hybridised with a radioactive probe and autoradiography is used for detection. The regions where mutation is present in the gene will not appear in the photographic film since probe will not be able to bind

with that part.

Transgenic Animals & Biopiracy

Transgenic Animals

- Animals that have their DNA manipulated to possess or express an extra gene are called transgenic animals.
- Till date, transgenic rats, rabbits, pigs, sheep, cows, and fish have been produced.

Reasons for Producing Transgenic Animals

- **Study of normal physiology**
  - Transgenic animals serve as models to study genetics, regulation and down regulation of genes, and their corresponding effects on physiology.
  - They give information about the biological role of a particular factor in the body.
- **Study of diseases**
  - They act as models to study the genetic basis of diseases.
  - These studies aid in finding possible treatments of diseases.
  - Transgenic models exist of various human diseases such as cancer, cystic fibrosis, rheumatoid arthritis, Alzheimer' s, etc.
- **Biological products**
  - Treatment of diseases often requires certain products that are expensive to make.
  - Transgenic animals can be produced that have genes, coding for that particular product.

- Example – Human protein α-1-antitrypsim used to treat emphysema is isolated by this method.
- In 1997, first transgenic cow Rosie produced human protein enriched milk, which contained α-lactalbumin and was nutritionally more suitable for human babies.

- **Vaccine safety tests**
  - Transgenic mice are used to test vaccines for their safety before they are used for humans.
  - Example – Transgenic mice are used to check polio vaccines.
- **Chemical safety testing**
  - Transgenic animals contain genes that make them more sensitive to toxic substances than non-transgenic.
  - Toxicity testing in such animals helps us to obtain results in less time.

Ethical Issues Associated with Transgenic Animals

- The Indian government has set up an organisation GEAC (Genetic Engineering Approval Committee), which makes decisions regarding validity of GM research and its use for public utility.
- Modification which may result in the loss of biological significance of animals cannot go beyond regulation.
- Unpredictable results may be observed, if these organisms are introduced into the natural ecosystem.
- Patents for transgenic varieties also create problems as many indigenous varieties are claimed by multinational companies as their own inventions.

- For example – A new variety of Basmati was claimed by an American company through patenting. This new variety was actually derived by Indian farmers by crossing Indian Basmati with semi dwarf varieties.
- Similarly Neem and turmeric, which have been used for ages in Indian medicines, are also matters of dispute for patent rights.

Biopiracy

- Use of bio-resources by MNCs and other organisations without proper authorisation from countries and people concerned without compensatory payment
- Industrialised and developed nations are economically rich, but poor in biodiversity while opposite prevails for developing nations. Therefore, developed countries exploit traditional knowledge and resources of poor countries for commercialisation.
- This is a matter of injustice since inadequate compensation and benefit sharing is given to poor countries in return. Therefore, steps should be taken by developing countries to prevent this exploitation.
- The Indian parliament has recently introduced second amendment of Indian patents bill to deal with these issues.