BIOTECHNOLOGY

1. Biotechnology Applications

The applications of biotechnology include

(i) Therapeutics

(ii) Diagnostics

(iii) Genetically modified crops for agriculture

(iv) Processed food

(v) Bioremediation

(vi) Energy production and

(vii) Waste treatment

The three critical research areas of biotechnology are:

(i) Providing the best catalyst in the form of improved organism, usually in the form of a microbe or pure enzyme.

(ii) Creating optimal conditions through engineering for a catalyst to function and

(iii) Downstream processing technologies to purify the protein/organic compound.

2. Application of biotechnology in Agriculture

The three options for increased food production are:

(i) Agrochemical-based agriculture.

(ii) Organic agriculture and

(iii) Genetically engineered crop-based agriculture.

The Green Revolution succeeded in increasing the yield of crops mainly due to

(i) Use of improved varieties of crops and

(ii) Use of agrochemicals (fertilizers and pesticides).

Further increase in the yield with the existing varieties of crops is not possible using conventional methods of breeding.

Agrochemicals cause pollution of soil and water and are too expensive for the farmers.

The use of genetically modified plants has been useful in the following ways:

(i) Genetic modification has made the crops more tolerant to abiotic stresses like cold, heat, drought, salinity, *etc.*

(ii) It has reduced the dependence of crops on chemical pesticides as they are made pest-resistant.

(iii) Post-harvest losses are much reduced.

(iv) As the plants have increased efficiency of mineral usage by plants, the early exhaustion of fertility of soil is prevented.

(v) Food produced from GM (Genetically Modified) crops has enhanced nutritional value.

(vi) Genetic modification has been used to create tailor-made plants to supply resources to industries such as starch, fuels, pharmaceuticals, *etc.*

3. Production of Pest-Resistant Plants

***(a)* Bt Cotton.**

* The soil bacterium, *Bacillus thuringiensis* produces crystal proteins called Cry proteins that are toxic to larvae of insects like tabacco budworm, armyworm, beetles and mosquitoes.
* The Cry proteins exist as inactive protoxins and get converted into active toxin when ingested by the insect, as the alkaline pH of the gut solubilises the crystals.
* The activated toxin binds to the surface of epithelial cells of midgut and creates pores.
* This causes swelling and lysis of cells leading to
* This causes swelling and lysis of cells leading to the death of the insect (larva).
* The genes *(cry* genes) encoding this protein are isolated from the bacterium and incorporated into several crop plants like cotton, tomato, corn, rice, soybean, *etc.*
* The proteins encoded by the following *cry* genes control the pest given against them. *cry I Ac* and *cry II* Ab control cotton bollworms.

  cry I Ab controls corn borer.

  cry III Ab controls colarado potato beetle.

  cry III Bb controls corn rootworm.

(b) Protection against Nematodes.

* A nematode called *Meloidogyne incognita* infects tobacco plants and reduces their yield.
* The specific genes (in the form of cDNA) from the parasite are introduced into the plant using *Agrobacterium* as the vector.
* The genes are introduced in such a way that both sense/coding RNA and antisense RNA (complementary to the sense/coding RNA) are produced.
* Since these two RNAs are complementary, they form a double stranded RNA (ds RNA).
* This silences the specific RNA of the nematode, by a process called RNA-interference; it prevents the translation of a specific mRNA (silencing).
* As a result, the parasite cannot live in the transgenic host and the transgenic plant is protected from the pest.

4. Application of Biotechnology in Medicine

The rDNA technology has been used in the production of safe and more effective therapeutic drugs.

The recombinant therapeutics do not induce unwanted immunological responses that are commonly observed with similar products isolated from non-human sources.

At present about thirty recombinant therapeutics have been approved for human use, of which twelve are being marketed in India also.

***(a)* Genetically Engineered Insulin (Humulin)**

* Human insulin consists of two short polypeptide chains: chain A and chain B, linked by disulphide bridges.
* Insulin is secreted as prohormone which has to be processed, before it becomes a mature and functional hormone.
* The prohormone contains another polypeptide, called C-peptide, which is removed during maturation.
* In 1983, Eli Lilly, an American company, prepared two DNA sequences coding for chains A and B of human insulin and introduced them into the plasmids of *Escherichia coli* to produce insulin.
* The two chains produced were extracted and combined by creating disulfide bridges.

***(b)* Gene Therapy:**

* In this method, genes are inserted into the cells and tissues of an individual to correct certain hereditary diseases.
* It involves the delivery of a normal gene into the individual or embryo to replace the defective mutant allele of the gene.
* Viruses which attack the host and introduce their genetic material into the host, are all used as vectors.
* The first clinical gene therapy was given in 1990 to a four year old girl with adenosine deaminase (ADA) deficiency.
* ADA deficiency can be cured by the following methods:

  (i) Bone marrow transplantation in some children, but it is not completely curative.

  (ii) Enzyme replacement therapy, in which the functional ADA is injected into the patient.

  (iii)Gene therapy, in which functional gene is introduced into the body.
* For gene therapy, lymphocytes were grown in a culture and functional ADA cDNA is then introduced into these lymphocytes.
* These lymphocytes are then transferred into the body of the patient; the patient requires periodic infusion of such genetically-engineered lymphocytes, as these cells have a specific lifespan.
* If a functional gene is introduced into the bone marrow cells at early embryonic stage, it would be a permanent cure.

(iii) Molecular Diagnosis.

* Recombinant DNA molecules and techniques like PCR (Polymerase Chain Reaction) are used for early diagnosis of disorders.
* Cloned genes when expressed to produce recombinant proteins help in developing sensitive diagnostic techniques like ELISA.
* The cloned genes are also used as 'probes' to detect the presence of complementary DNA strand.
* A probe is a piece of single stranded DNA, that is tagged with a radioactive molecule and it is used to find its complementary DNA by hybridization.
* It is followed by detection of radioactivity by autoradiography.
* Presence of a normal or mutant gene can be detected using such a method.
* PCR is used to detect HIV and to detect mutations in genes of suspected cancer patients.

5. Transgenic Animals.

Transgenic animals are those animals that have had their DNA manipulated to possess and express a foreign gene.

Transgenic animals are used in the following ways:

(i)Transgenic animals can be specifically designed to allow the study of how genes are regulated and how they affect the normal functions of the body and its development, *e.g.,* Information is obtained about the biological role of insulin-like growth factor.

(ii)Transgenic animals are designed to increase our understanding of how genes contribute to the development of diseases; they are made to serve as models for human diseases.

(iii) Transgenic animals that produce useful biological compounds can be created by introducing a portion of DNA that codes for that product from other organism(s), *e.g.,* alpha-1 antitrypsin, a human protein used to treat emphysema.

The first transgenic cow, Rosie, produced the human protein-enriched milk; it contained human alpha-lactalbumin (2.4g/litre), a more nutritionally balanced product for human babies.

(iv) Transgenic mice are being developed for use in testing the safety of vaccines. *(e.g.* polio vaccine).

(v)Transgenic animals with more sensitivity to toxic substances are being developed to test the toxicity of drugs; this will produce the results in less time.

6. Ethical Issues

Genetic modification of organisms can have unpredictable/undesirable effects when such organisms are introduced into the ecosystem.

The modification and use of such organisms for public services has also resulted in problems with the granting of patents.

Hence, the Indian Government has set up organisations which are authorised to make decisions regarding the validity of genetic modifications and the safety of introducing genetically modified organisms for public services.

One such organization is the Genetic Engineering Approval Committee (GEAC).

7. Biopiracy

The industrialized/developed nations are rich financially, but poor in biodiversity and traditional knowledge, while the developing and underdeveloped countries are rich in bio resources and traditional knowledge.

Some such developed countries use the bio resources and traditional knowledge of the other countries without proper authorisation and/or compensation to the countries concerned (Biopiracy).

Basmati rice grown in India is distinct for its unique flavour and aroma, but an American company got patent rights on Basmati through the US patent and trademark office; the new variety of Basmati has been developed by this company by crossing an Indian variety with the semi-dwarf varieties.

Now some nations are developing laws to prevent such unauthorized exploitation of their bio resources and traditional knowledge.