* Biotechnology has varied applications, some of which include

1. Therapeutics
2. Diagnostics
3. Genetically modified crops for agriculture
4. Processed food
5. Bioremediation
6. Waste treatment
7. Energy production.

* There are three critical research areas of biotechnology :

1. Providing best catalyst as improved organism, usually a microbe or pure enzyme.
2. Creating optimal conditions by engineering for a catalyst to act.
3. Downstream processing technologies to purify the protein/organic compound.
4. Biotechnological Applications in Agriculture

* Food production can be increased by applying biotechnology by the following ways :

1. Agrochemical-based agriculture.
2. Organic agriculture.
3. Genetically engineered crop-based agriculture.

* The Green Revolution succeeded in increasing food supply because of

1. Use of improved crop varieties.
2. Use of agrochemicals (fertilizers and pesticides).
3. 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 organisms (GMOs)** are plants, bacteria, fungi and animals whose genes have been altered by manipulation.
* Genetic modification of crops have resulted in

1. Increased tolerance against abiotic stresses (cold, drought, salt, heat).
2. Reduced reliance on chemical pesticides (pest-resistant crops).
3. Reduced post-harvest losses.
4. Increased efficiency of minerals used by plants (this prevents early exhaustion of fertility of soil).
5. Enhanced nutritional value of food, e.g., vitamin ‘A’ enriched rice (golden rice).
6. Creation of tailor-made plants to supply alternative resources such as starches, fuels and pharmaceuticals to industries.
7. **Bt cotton**

* Some strains of *Bacillus thuringiensis* produce proteins that kill some insects like lepidopterans (tobacco budworm, armyworm), coleopterans (beetles) and dipterans (flies, mosquitoes).
* B. thuringiensis forms protein crystals which contain a toxic insecticidal protein.
* Bt toxins are initially inactive protoxins but after ingestion by the insect, their inactive toxin becomes active due to the alkaline pH of the gut, which solublises the crystals.
* The activated toxin binds to the surface of midgut epithelial cells thus creating pores which causes cell swelling and lysis, further leading to death of the insects.
* Specific Bt toxin genes obtained from *Bacillus thuringiensis* are used in several crop plants like cotton.
* The toxin is coded by a gene called *cry* which is of various types. For example, proteins encoded by the genes *cryIAc* and *cryIIAb* control the cotton bollworms and that of *cryIAb* control corn borer.
* Bt tobacco was first cultured to kill hornworm (*Manduca sexta*).

1. **Pest resistant plants**

* A nematode *Meloidegyne incognitia* infects the roots 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 *m*RNA due to a complementary *ds*RNA.
* *ds*RNA binds and prevents translation of the *m*RNA (**silencing**).
* By using *Agrobacterium* vectors, 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 (*ds*RNA) that initiates RNAi and hence silence the specific *m*RNA of the nematode.
* The parasite cannot survive in the transgenic host, so protects the plants from pests.

1. **Biotechnological Applications in Medicine**

* The recombinant DNA technology is used for production of therapeutic drugs which are safe and effective.
* It avoids unwanted immunological responses, commonly observed with similar products isolated from non-human sources.
* About thirty recombinant therapeutics have been approved for human use in the world including India.

1. Genetically engineered insulin

* Insulin contains two short polypeptide chains-chain A and chain B linked by disulphide bridges.
* In mammals, insulin is synthesised as a pro-hormone (that needs to be processed to become mature and functional hormone). It contains an extra stretch called G peptide.
* C peptide is absent in mature insulin and is removed during maturation into insulin.
* Earlier, insulin was extracted from pancreas of slaughtered caule and pigs but some patients began developing allergies.
* Production of insulin by rDNA 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 plasmids of *E. coli* for production. The A and B chains produced, were separated, extracted and combined, by creating disulfide bonds to form human insulin.

1. **Gene therapy**

* **Gene therapy** is a collection of methods that allows correction of gene defects, 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. Blease** and **W.F. Andresco** 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.
* Lymphocytes from patient’s blood were grown in a 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 diseases like cystic fibrosis, haemophilia, cancer, Parkinson’s, etc., are also treated by gene therapy.

1. **Molecular diagnosis**

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

1. **Polymerase chain reaction**

* Low concentration of the pathogen in the body does not allow its detection.
* The nucleic 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 mutations in suspected cancer patients.

1. **Recombinant DNA technology**

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

1. Enzyme linked immune-sorbent assay (ELISA)

* It is based on the principle of antigen-antibody interaction.
* Either the presence of antigens (proteins, glycoprotein, etc.) are detected or the antibodies produced against the pathogen are detected.

1. **Stem Cell Technology**

* **Stem cells** are undifferentiated biological cells. These can differentiate into specialized cells and can divide to produce more stem cells.
* Stem cells are found in multicellular organisms.
* Adult stem cells are used in medical therapies, for example, in bone marrow transplantation.
* Stem cells can also be taken from umbilical cord blood just after birth.

1. **Transgenic Animals**

* Animals whose DNA is manipulated to possess and express an extra (foreign) gene are known as **transgenic animals**. 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.
* For example, study of complex growth factors like insulin-like growth factor.

1. **Study of disease**

* Study of genes which are responsible for diseases in human and their treatment.
* Transgenic models have been developed for many human diseases like cancer, cystic fibrous, rheumatoid arthritis and Alzheimer’s disease.

1. **Biological products**

* Useful biological products can be produced by introducing into transgenic animals, the portion of DNA (or genes) which codes for a particular product.
* For example, human protein (α-1-antitrypsin) is used to treat emphysema.
* 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.

1. **Vaccine safety**

* Transgenic mice are developed to test safety of vaccines, before being used on humans.
* For example, polio vaccine.

1. **Chemical safety testing**

* Transgenic animals are made to carry genes, which make them more sensitive to the toxic substances than non-transgenic animals.
* On exposing to the toxic substances, their effects are studied in less time.

1. **Ethical Issues**

* Genetic modification of organisms show unpredictable results when such organisms are introduced into the ecosystems.
* The modification and use of living organisms for public services (as food and medicine sources, for example) creates problems with patents granted.
* Government of India formed the organisations like **GEAC** (Genetic Engineering Approval Committee) to decide the validity and safety of GM organisms for public safety.
* Angered public is questioning that certain companies granted patents for products and technologies which are grown, identified and used by farmers and indigenous people related to a specific region/country.
* Rice is being used since thousands of years in Asia’s agricultural history, of which 200,000 varieties are in India alone.
* Basmati is unique for its aroma and flavor, whose 27 varieties are cultivated in India.
* In 1997, an American company got patent rights for the Basmati rice through the US Patent and Trademark Office, and was allowed to sell a ‘new variety’ in US and abroad.
* This new variety of Basmati was derived from Indian farmer’s varieties.
* Indian Basmati was crossed with semi-dwarf varieties and claimed as an invention or a novelty.
* Besides Basmati rice, now attempts are in progress for turmeric and neem.
* Our rich legacy will be reduced by other countries/individuals, if we do not pay attention or counter these patent applications.

1. **Biopiracy**

* Biopiracy is defined as the use of bioresources by multinational companies and other organizations, without proper authorization from the countries and concerned people, without compensatory payment.
* Generally, financially rich nations are poor in biodiversity and traditional knowledge, while developing and under-developed nations are rich in biodiversity 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 commercialisation.
* Some nations are developing laws, to prevent such unauthorised exploitation of their bioresources and traditional knowledge.
* To check these problems, Indian Parliament has recently cleared the second amendment of the **Indian Patents Bill**, that takes such issues into consideration.

1. **Patent**

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