

Biotechnology and Its Applications

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- **Biotechnology** involves the **industrial-scale production** of biopharmaceuticals and biologicals using genetically modified microbes, fungi, plants, and animals.
- It plays a significant role in enhancing the quality of human life through applications in healthcare, agriculture, environment, and industry.

Major Applications of Biotechnology

Therapeutics

- Production of life-saving drugs and vaccines.

Diagnostics

- Development of advanced tools for disease detection.

Genetically Modified (GM) Crops

- Improving yield, quality, and resistance in agriculture.

Processed Food

- Enhancing nutritional value, shelf life, and safety.

Bioremediation

- Using organisms to clean up environmental pollutants.

Waste Treatment

- Managing and reducing industrial and municipal waste.

Energy Production

- Biofuels and renewable energy from biological sources.

Critical Research Areas in Biotechnology

1. Providing the Best Catalyst

- Developing improved organisms (usually microbes) or pure enzymes for industrial processes.

2. Creating Optimal Conditions

- Using engineering solutions to ensure maximum efficiency of catalysts.

3. Downstream Processing Technologies

- Purifying the desired protein or organic compound to obtain the final product.

Biotechnological Applications in Agriculture

- To increase food production, **three major agricultural approaches** can be considered:
 1. Agrochemical-based agriculture – Using chemical fertilizers and pesticides.
 2. Organic agriculture – Relying on natural farming methods without synthetic chemicals.
 3. Genetically engineered crop-based agriculture – Using biotechnology to develop improved crop varieties.

Limitations of Conventional Agriculture

- The **Green Revolution** significantly increased food supply, tripling production.
- Yield improvements came mainly from improved crop varieties, better management, and **agrochemical use**.
- In developing countries, agrochemicals are expensive, and further yield improvement with conventional breeding is limited.
- Traditional breeding methods are **slow** and sometimes **inefficient** in meeting growing demands.

Tissue Culture Technology

Definition:

- The technique of growing plant cells, tissues, or organs under sterile conditions on nutrient media.

Totipotency:

- The ability of a single plant cell/explant to regenerate into a complete plant.

Nutrient Medium Requirements:

- **Carbon source:** Sucrose
- Inorganic salts
- Vitamins & amino acids
- **Growth regulators:** Auxins, cytokinins

Micropropagation:

- Large-scale production of thousands of genetically identical plants (somaclones) in a short time.
- Commercially used for crops like **tomato, banana, apple**.

Applications of Tissue Culture

1. Virus-free plants:

- Meristem culture can eliminate viruses from infected plants (e.g., banana, sugarcane, potato).

2. Somatic hybridisation:

- Isolation of **naked protoplasts** (cell without cell wall).
- Fusion of protoplasts from different plant varieties to produce **somatic hybrids**.
- Example: **Pomato** (tomato × potato) – not commercially successful due to incomplete desirable traits.

Genetically Modified Organisms (GMOs)

Definition:

- Plants, bacteria, fungi, or animals whose genes have been altered by genetic engineering.

Benefits of GM Plants:

1. Tolerance to abiotic stresses (cold, drought, salt, heat).
2. Reduced need for chemical pesticides (pest-resistant crops).
3. Decreased post-harvest losses.
4. Improved mineral usage efficiency → prevents early soil fertility loss.
5. Enhanced nutritional value (e.g., **Golden Rice** enriched with Vitamin A).
6. Production of tailor-made plants for industrial use (starches, fuels, pharmaceuticals).

Pest-Resistant Plants via Bt Technology

Bt Toxin and Its Mode of Action

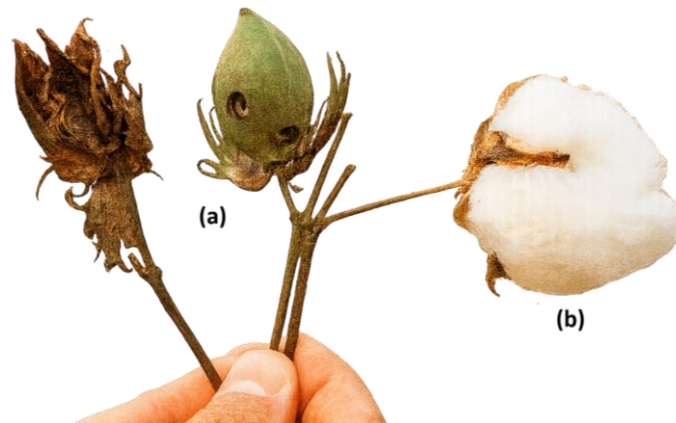
- Produced by **Bacillus thuringiensis** (Bt).
- Effective against certain insect groups:
 - **Lepidopterans** – Tobacco budworm, armyworm.
 - **Coleopterans** – Beetles.
 - **Dipterans** – Flies, mosquitoes.
- Bt forms protein crystals containing insecticidal protoxins.
- Insects ingest protoxin → alkaline pH in gut activates toxin → binds to midgut epithelial cells → forms pores → cell swelling, lysis, and death.

Genetic Engineering of Bt Crops

- Specific Bt genes (**cry genes**) are isolated and inserted into crops (cotton, corn, rice, tomato, potato, soybean).
- Gene selection depends on target pest:
 - **cryIAc & cryIIAb** → Cotton bollworm resistance.
 - **cryIAb** → Corn borer resistance.

Example:

- **Bt Cotton** – Provides resistance to cotton bollworms without external insecticide use.



Cotton boll: (a) destroyed by bollworms; (b) a fully mature cotton boll

Nematode-Resistant Plants via RNA Interference (RNAi)

Problem

- *Meloidogyne incognita* (root-knot nematode) infects roots of tobacco and reduces yield.

RNAi Mechanism

- **RNA interference:** Natural defense mechanism in eukaryotes involving silencing of specific mRNA by complementary double-stranded RNA (dsRNA).
- dsRNA binds to mRNA → prevents translation → silences gene expression.

Genetic Engineering Approach

- Agrobacterium vectors introduce nematode-specific DNA into plants.
- Transgene produces **sense and antisense RNA** → form dsRNA → triggers RNAi.
- Result: Nematode-specific mRNA is silenced → nematode cannot survive → plant is resistant.

Example Crops

- Transgenic tobacco resistant to root-knot nematode.

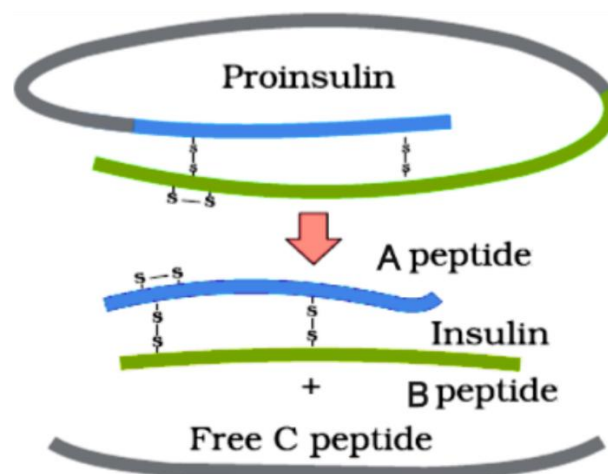
Biotechnological Applications in Medicine

- Recombinant DNA (rDNA) technology has transformed **healthcare** by enabling **large-scale production** of safe, effective therapeutic drugs.
 - These **recombinant therapeutics** are free from unwanted immunological reactions often caused by products from non-human sources.
 - Globally, about 30 recombinant therapeutics have been approved for human use, and in **India, 12** are currently marketed.
- Major medical applications include:
 - Genetically Engineered Insulin
 - Gene Therapy
 - Molecular Diagnosis

Genetically Engineered Insulin

Background

- **Diabetes mellitus** (especially adult-onset) can be managed by regular insulin administration.
- Earlier, insulin was extracted from the pancreas of cattle and pigs.
 - Drawbacks: Caused allergic reactions in some patients due to it being a foreign protein.
- Human insulin is made up of two short polypeptide chains:
 - **Chain A** and **Chain B** linked by disulphide bridges.
- In the human body, insulin is produced as a pro-hormone containing an extra **C-peptide**, which is removed during maturation to form functional insulin.



Maturation of pro-insulin into insulin (simplified)

Challenge in rDNA Production

- Producing **mature insulin** via recombinant techniques required correct assembly of chains A and B.

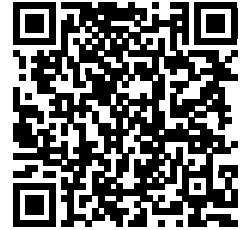


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