8 BIOTECHNOLOGY

Students Learning Outcomes

After studying this chapter, students will be able to:

- Introduce biotechnology.
- Explain the role of yeast in the production of bread and ethanol.
- Understand that bacteria are useful in biotechnology and genetic modification.
- Describe the basic method of genetic engineering/genetic modification.
- Discuss potential advantages and risks of genetic modification.

Biotechnology is a new branch of biology that deals manipulation of organisms at molecular and cellular level to get services and products beneficial for human welfare. This field provides benefits in the areas of human health, agriculture, industries, and environment. In this chapter, we will study the basics of biotechnology and its useful applications.

8.1 INTRODUCTION OF BIOTECHNOLOGY

In 1919, Hungarian engineer **Karl Ereky** first proposed the term "biotechnology". It may be defined as the use of living cells or organisms to create products or processes for specific purposes. Through this technology;

- The hereditary characteristics of organisms are modified.
- New organisms with desired characters are developed from a cell or a part of an organism.
- Any required substance is produced from the modified organism.

Modern biotechnology emerged after the invention of the structure and function of DNA in 1953. The techniques being used in modern biotechnology include fermentation, recombinant DNA technology, cell culture, gene editing, genetic engineering, and tissue culturing etc.

Sir Ian Wilmut is a British embryologist. He was the leader of the research group that in 1997 first produced a mammal (a lamb named Dolly) from an adult body cell.

Importance of Yeast in Fermentation

Yeast is a microscopic fungus that plays a crucial role in both bread making and ethanol production through a process called fermentation.

Fermentation is the oldest form of biotechnology. It is used for making bread, beer, and yogurt thousands of years ago.

Role in Bread Making

Yeast ferments the sugars present in the dough and produces carbon dioxide (CO_2) gas. This gas forms bubbles in the dough, causing it to rise and become soft and airy. The alcohol produced during this process evaporates during baking.

Role in Ethanol Production

Yeast ferments sugars from crops like sugarcane or corn to produce ethanol (alcohol) and carbon dioxide. The ethanol is then purified and used as a biofuel or in alcoholic beverages.

Importance of Bacteria in Biotechnology

Bacteria are essential microorganisms used in biotechnology because they are simple, fast-growing, and can easily accept new genetic material. Scientists use them for producing medicines, studying genes, and creating **genetically modified organisms (GMOs)**.

Role in Biotechnology

Certain bacteria produce important substances like antibiotics (e.g., *Streptomyces* produces streptomycin). Many bacteria produce enzymes which scientists use in making cheese and detergents. Similarly, many bacteria produce vitamins (like vitamin B12). Scientists also use bacteria to clean up oil spills and waste through a process called **bioremediation**. In the food industry, bacteria like *Lactobacillus* help in making yogurt and cheese by fermenting milk.

Role in Genetic Modification

Scientists use special structures called plasmids (small loops of DNA found in bacteria) as carriers to introduce new genes into bacterial cells. In this way, the modified bacteria start producing proteins from that foreign gene. This method is used to produce:

- Human insulin for treating diabetes
- Human growth hormone for growth disorders
- Vaccines against diseases

Some bacteria are also used to introduce new genes into plant cells during the creation of genetically modified crops.

8.2 GENETIC ENGINEERING

Genetic engineering is defined as the process of altering (editing) the genes of organisms or transferring the genes from one organism into other organisms. In genetic engineering, special enzymes are used to cut and attach DNA at specific locations. As a result of genetic engineering, **Genetically Modified Organisms** are produced. The following are the two main examples of genetic engineering.

1. Gene Editing

Gene editing is a technique in which scientists make changes in the DNA (genes) of an organism. These can involve adding, removing, or replacing specific parts of DNA. It allows scientists to add, delete, or change parts of the DNA. It is done to correct genetic abnormalities and to improve characteristics.

Examples of Gene Editing

1. **Curing Genetic Diseases:** Scientists are researching how gene editing can cure diseases caused by abnormal genes, such as sickle cell anaemia (a blood disorder), cystic fibrosis (a lung disease).
2. **Improving Crops:** Gene editing can create crops that grow faster, resist

Gene editing is done very carefully because changes made to DNA can have unexpected effects.

pests and diseases, and survive droughts better. For example, virus resistant varieties of tomato and tobacco have been developed. Modified varieties of soybeans, corn, tomato, and cotton have been produced which show resistance against herbicides.

3. **Producing Better Medicines:** Gene editing helps create bacteria that produce important medicines, like insulin for diabetes.

2- Gene Transfer

Genetic engineers use special **vectors** to transfer genes into an organism.

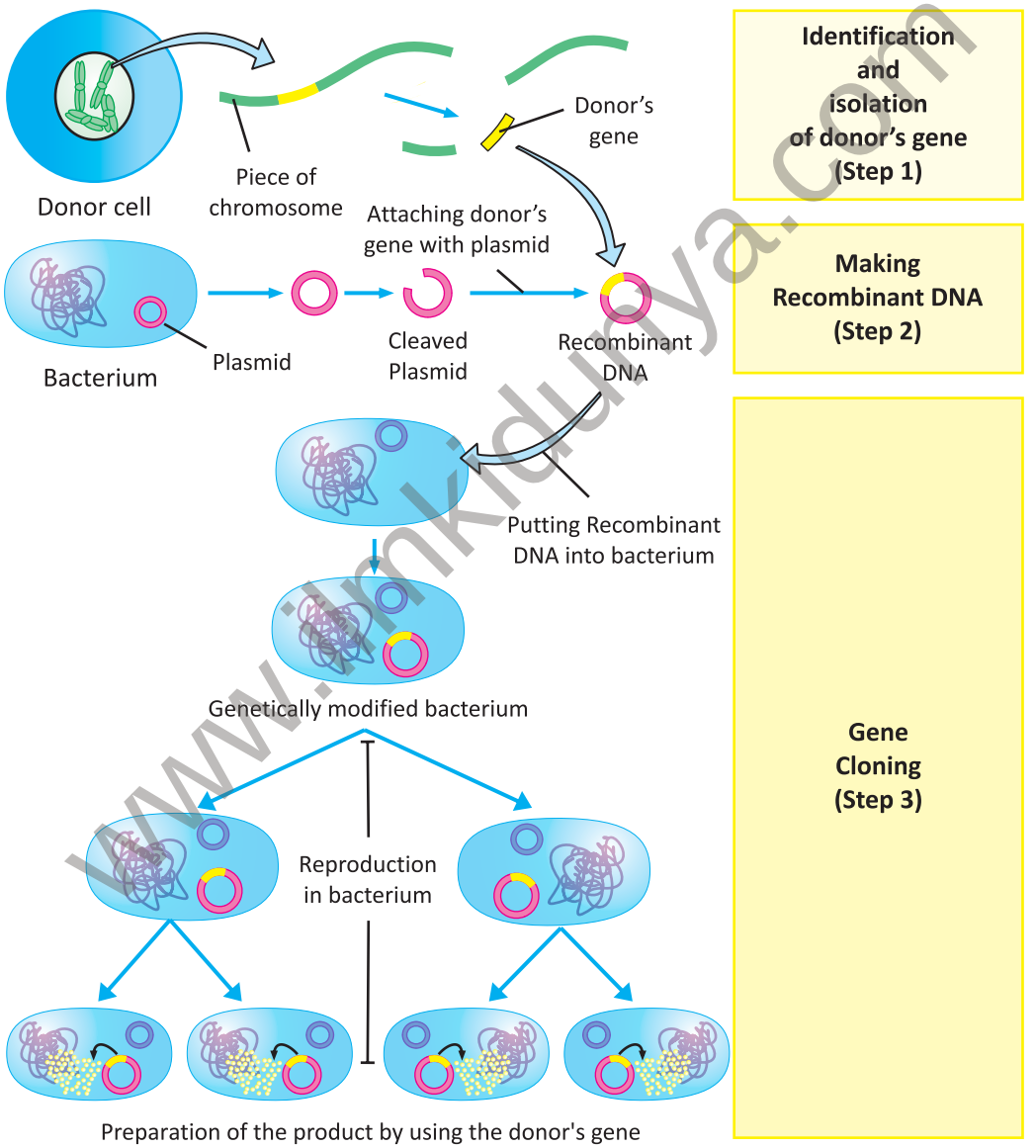


FIGURE 8.1: Transfer of gene to an organism and its cloning

The most commonly used vectors to transfer genes into bacteria are plasmids and bacteriophages. **Plasmids** are small, circular DNA molecules present in some bacteria. **Bacteriophages** are the viruses that can enter bacteria. The following are the steps for transferring a gene into organism e.g. bacteria.

1. The gene of donor organism is **identified** and **isolated** from its chromosome.
2. A plasmid is removed from a bacterial cell. The plasmid DNA is cut. Donor's gene is attached at the cut ends of the plasmid. The plasmid is now a combination of its original DNA and the new DNA (donor's gene). Now it is called **recombinant DNA**.
3. The recombinant DNA is transferred into a bacterial cell. When bacterial cell reproduces to form a colony of cells, all genetically modified bacteria contain the recombinant DNA. In this way, the bacterial colony contains many copies of the donor's gene. This step is also called **gene cloning**.

Examples of Gene Transfer

1. The human insulin gene is transferred into a bacterium. The modified bacteria produce insulin, which is collected for treating diabetic patients.
2. Human growth hormone is produced in genetically modified bacteria. It is used to treat dwarfism.
3. Interferon (anti-virus protein) is made in modified bacteria.
4. In gene therapy, genetic engineers introduce genes into a patient's cells. It is used to treat genetic disorders of blood (e.g., thalassaemia).
5. Vaccine against Hepatitis B virus has been produced from yeast through genetic modification.
6. A gene from a bacterium is transferred into cotton and corn crops. The genetically modified crops then produce a natural toxin that kills insects but is safe for humans.
7. Gene from a bacterium is transferred into rice plants. The rice produces beta-carotene, which the body converts into vitamin A. Such genetically modified rice help prevent blindness caused by vitamin A deficiency.

Some COVID-19 vaccines are made by using mRNA. This mRNA carries instructions to make a harmless proteins of the corona virus, which trains the immune system to fight the real virus.

FIGURE 8.2: Golden rice & White rice

Table 8.1: Products made by using Gene Transfer			
Product	**Genetic Material Transferred**	**Organism or Technology Used**	**Purpose**
Insulin	Human insulin gene	Bacteria	Treat diabetes
Growth Hormone	Human growth hormone gene	Bacteria	Treat growth disorders
Interferon	Human interferon gene	Bacteria	Treat viral infections and boost immunity
Hepatitis B Vaccine	Surface protein gene of Hepatitis B virus	Yeast cells	Protect against Hepatitis B
Bt Crops	Bt toxin gene	Cotton, Corn plants	Insect resistance
Golden Rice	Beta-carotene producing genes	Rice plants	Prevent vitamin A deficiency

8.3 APPLICATIONS OF BIOTECHNOLOGY

The following are the applications of biotechnology.

1. Food Biotechnology

- Biotechnologists have developed virus resistant, pest resistant, and drought resistant varieties of many crop plants.
- Enzymes extracted from certain microbes are used in different industries for the production of alcohol.

Research in Pakistan has led to the development of rice varieties that are resistant to certain diseases and pests.

Pakistan has also advanced in using tissue culture technology for the mass propagation of high-yielding fruit crops such as mangoes and citrus.

2. Medical Biotechnology

In medical field, biotechnology is helping in the following:

- Making proteins e.g., hormones and enzymes used for treating various diseases.
- Developing vaccines to prevent viral and bacterial infections.
- Correcting defective genes responsible for genetic disorders.
- Production of targeted antibodies for disease diagnosis and treatment.
- Identifying inherited diseases and genetic conditions early.

In humans, more than 3500 disorders are due to errors in genes. Biotechnologists are trying to remove such disorders through biotechnology.

In **Human Genome Project**, biologists discovered the locations of all genes in human body. They also found the characteristics controlled by each gene.

3. Environmental Biotechnology

Environmental Biotechnology is the application of biological organisms or processes to protect and improve the environment.

Bioremediation is defined as the use of organisms such as bacteria, plants, or fungi to remove or neutralize pollutants from the environment. Genetically modified bacteria are used to break down the harmful chemicals present in waste matters and industrial discharge.

FIGURE 8.3: Saplings to grow forest

- Large number of saplings of different plants are produced through tissue culture. These saplings are planted to grow new forests in limited time.
- Modified bacteria are also used for extracting different minerals e.g., copper and uranium.
- Microbes such as bacteria, blue green algae and fungi are used to produce manure.

4. Marine Biotechnology

It deals with the marine organisms to develop new products, treatments, and technologies. For example:

- Genetic modifications in many fishes have led to faster growth rates.
- Compounds extracted from marine organisms (sponges, corals, and marine bacteria) are used to develop new cancer drugs, antibiotics and antiviral medicines.
- Certain marine bacteria are used to degrade oil spills, helping to clean up marine environments.
- Marine algae are cultivated in large quantities and processed into biodiesel, ethanol, and other types of renewable energy.
- Enzymes extracted from marine organisms are used in various industries. For example, an enzyme extracted from marine bacteria is used to produce high-fructose corn syrup (common sweetener in the food industry).

5. Industrial Biotechnology

The following are the main applications of industrial biotechnology.

- Biofuels like ethanol, biodiesel, and biogas are produced. For example,

yeast is used to ferment sugars from crops (corn, sugarcane) into ethanol. This ethanol can be blended with petrol to produce a cleaner fuel.

- Biodegradable plastic (bioplastic) is produced from fermented plant starch (usually corn or sugarcane).
- Pharmaceutical products are prepared through microbial fermentation and genetic engineering. For example, the production of antibiotics, such as penicillin, involves the fermentation of specific molds like *"Penicillium"*. Similarly, human insulin is produced through bacteria.

8.4 POTENTIAL RISKS OF BIOTECHNOLOGY

Health Concerns: Some people worry that consuming genetically modified foods could cause allergic reactions or long-term health problems. There is also concern that new genes might interact with human cells in unexpected ways.

Environmental Impact: GM plants can sometimes cross-pollinate with wild plants. So, the modified genes can be spread in natural ecosystems. It can lead to create such species that may harm the environment.

Loss of Biodiversity: If farmers mostly grow GM crops then traditional and naturally diverse varieties might become rare or extinct. This can reduce biodiversity.

Development of Resistant Pests and Weeds: Pests exposed repeatedly to GM crops may evolve into "powerful pests" that are no longer affected by the crop's built-in defences.

Ethical Issues: Many people feel that it is morally wrong to alter the natural genes of living organisms.

EXERCISE

A. Select the correct answers for the following questions.

1. Why are bacteria commonly used in genetic engineering for producing products?

a) They naturally produces the required products

b) They grow quickly and accept human genes

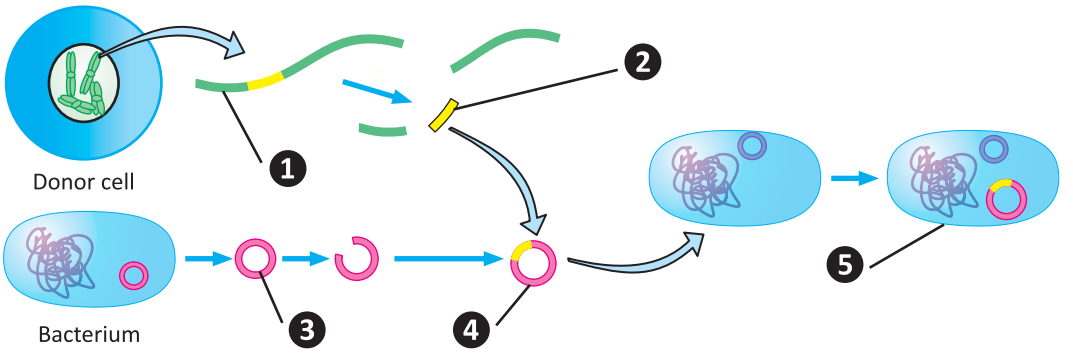
c) They resist all infections

d) They have a human-like immune system

2. In genetic engineering, the first step is:
   a) Inserting DNA into the organism
   b) Cutting the desired gene from DNA
   c) Growing the modified organism
   d) Making proteins from the gene
3. Which of these is often used as a vector in genetic engineering?
   a) Virus b) Fungi c) Yeast d) Blood cell
4. In genetic engineering, the desired gene is usually inserted into a bacterium by using:
   a) Protein b) Another bacterium
   c) Vector d) Enzyme
5. In genetic engineering, after inserting the gene, the host cell is allowed to:
   a) Mutate randomly b) Die naturally
   c) Multiply and express the gene d) Produce waste
6. In genetic engineering, "recombinant DNA" means:
   a) Natural DNA b) DNA copied by mistake
   c) DNA joined from two sources d) DNA destroyed by enzymes
7. A gene for toxin production is inserted into a plant for:
   a) Reducing water need b) Increasing vitamin content
   c) Resisting insect attacks d) Speeding up flowering
8. Genetically modified bacteria produce the following products, except;
   a) Hepatitis B vaccine b) Growth hormone
   c) Insulin d) Interferon
9. Which biotechnology products help against viral infections?
   a) Antibiotics b) Vaccines
   c) Clotting factors d) Growth hormone
10. Golden rice is a genetically modified plant to increase:
   a) Protein b) Vitamin A
   c) Iron d) Calcium

B. Write short answers.

1. What is the relation between biotechnology and genetic engineering?
2. What is a plasmid? Why biologists use plasmids in genetic engineering?
3. The following diagram shows how a gene is transferred to bacterial cell. Identify the structures labelled as 1 to 5.



4. What do you mean by genecally modified organism?
5. List two types of medical products that can be produced using genetic engineering.
6. List two ways by which genetic engineering may improve crops.

C. Write answers in detail.

1. Explain with examples that food biotechnology has advanced agriculture.
2. Explain with examples that medical biotechnology has advanced healthcare in diabetes and cancer.
3. Explain the role of yeast in the production of bread and ethanol.
4. Enlist the steps for transferring a human gene into a bacterial cell.
5. Describe the advantages of gene editing.
6. Discuss the potential risks of genetic modification.

D. Inquisitive questions

1. How can inserting a gene into a plant make it pest-resistant?
2. How can biotechnology help in developing vaccines quickly, like for COVID-19?
3. Why is it important to carefully study the effects of genetically modified foods on health?