

04

Biotechnology

Which process is involved in making cheese and bread?

How has biotechnology revolutionized our world?

How does biotechnology help in agriculture?

Students' Learning Outcomes

After studying this chapter, students will be able to:

- Define biotechnology as the use of living cells and organisms in products and processes that can improve the quality of life.
- Illustrate how biotechnology is a disciplined field that has the potential to transform how we live.
- Discuss the applications of biotechnology in the Pakistani context and their effects on the people and the environment of Pakistan over time e.g., bread-making, making of yogurt and cheese, vaccines for immunization, insulin production, dyes, etc.
- Relate the use of biotechnology in food sciences in producing foods with higher nutritional value and improved taste and quality (how fermentation has been improved by genetically modified organisms or the introduction of certain genes to raise iron content in rice, can be taken as examples).

Application of knowledge in the areas like engineering and medicines, etc., is called technology. Biotechnology is the use of living cells and organisms in products and processes that can improve the quality of life. Microorganisms are used in making bread, yogurt, cheese, vinegar and several medicines. Fermentation, tissue culture and genetic engineering, etc., are the processes and techniques in which microorganisms are used for making many industrial products and in the research work. In this chapter, some principles and techniques used in biotechnology will be introduced. General applications of biotechnology in the fields of agriculture, environment, health, food production and preservation, etc., will also be discussed.

4.1 GENETIC ENGINEERING

Genes act as instructions to make specific substances (proteins) which are used for specific structural and physiological purposes in the body. Genetic engineering is an advanced technique in biotechnology in which scientists select and isolate the useful gene from one organism (donor organism) and insert it into another organism (usually bacterium). The organism that contains a foreign gene in its cells is called **transgenic organism**. The inserted gene produces the desired product (protein) in transgenic organism.

4.1.1 Importance of Bacteria in Genetic Engineering

The scientist use bacterial cell because it is very simple and easy to grow. It does not have an organized nucleus. The chromosome, consisting of DNA, floats in the cytoplasm. Additional circular pieces of DNA called **plasmids** are also present in the cytoplasm (Figure 4.1). Plasmids can be easily isolated from a bacterial cell and a gene can be attached with it. Plasmid can carry the attached foreign gene into the bacterium. In this way, plasmid acts as a carrier of a foreign gene. Another reason for using bacteria in genetic engineering is their fast rate of reproduction.

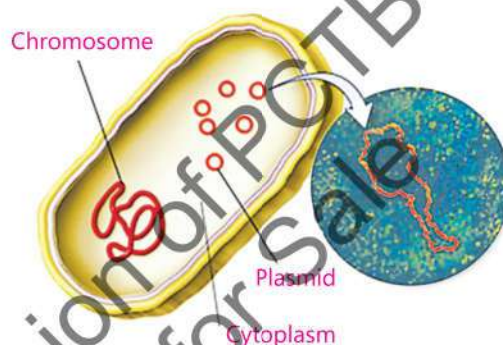


Figure 4.1 Bacterial cell

4.1.2 Introduction of Gene into Bacterium

The first step of genetic engineering for inserting a gene into a bacterial cell is the identification and isolation of the gene of desired protein from the donor organism (see Figure 4.2). An enzyme is used to cut the gene from the donor organism. The isolated gene is then attached with plasmid DNA taken from a bacterium. The same enzyme (used for cutting the donor gene) is used to cut the plasmid DNA at a specific site so that the gene can be attached at the cut end of the plasmid. The attached gene of desired protein and the plasmid DNA are collectively called **recombinant DNA**. The recombinant DNA is inserted back into the same type of bacterium from which the plasmid was isolated. The bacterium which takes in the recombinant DNA is called genetically modified bacterium (GM bacterium) or **transgenic bacterium** (Figure 4.2).

Do you know?

A bacterial cell divides to form two daughter cells within 20 minutes.

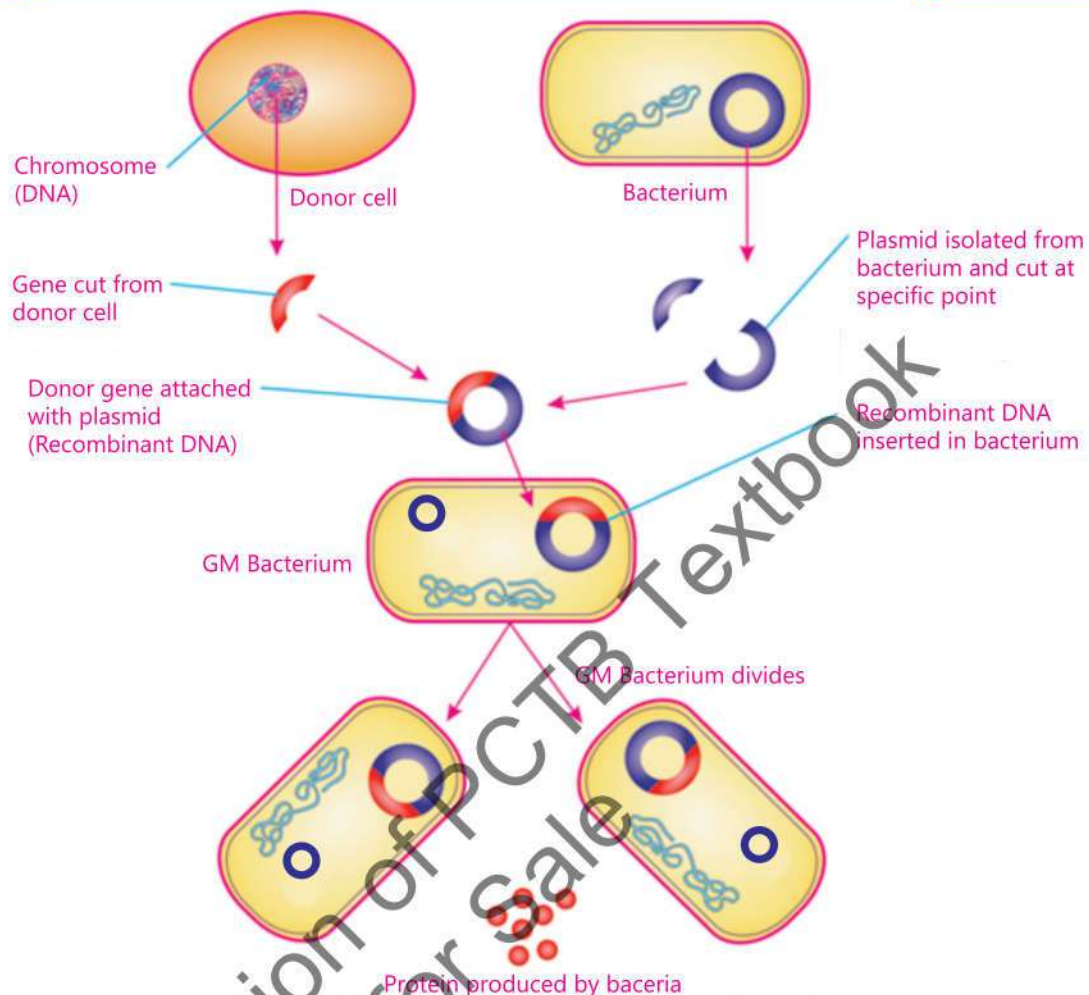


Figure 4.2 Introduction of gene into a bacterium

GM bacterium starts dividing and produces a bacterial colony. Every bacterium of the colony contains a copy of the gene of desired protein. When bacterial colony grows, it starts making proteins under the instructions of inserted gene.

In genetic engineering, genes of various useful proteins, e.g., insulin, enzymes for the synthesis of various medicines, vaccines, etc., are inserted in bacteria and desired proteins are obtained.

4.2 FERMENTATION

It is a catabolic process in which partial degradation of sugar occurs without the help of oxygen. Lactic acid fermentation by certain fungi and bacteria is used in the dairy industry to make cheese and yogurt. In bread making, the flour used contains starch, protein and an enzyme amylase. Yeast is added in the flour. The flour is mixed with water to form dough. The carbon dioxide produced causes the dough to rise and because of this cavities appear.

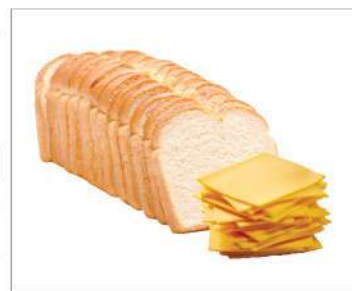


Figure 4.3 Bread and Cheese

4.3 BIOTECHNOLOGY PRODUCTS

Genetic engineers change the genetic material of organisms by the removal, addition or modification of genes. The organism whose genes are modified is called **Genetically Modified Organism** (GMO). It is the modern method to change the characters of organisms. For example, this process is used in crops to develop resistance in plants against disease-causing microorganisms. Similarly, the edible plants are genetically modified to improve the nutritional quality of plants. Moreover, GMOs are used to prepare useful products such as insulin and vaccines etc.

Insulin

Insulin is an animal protein, which is produced by pancreas. It controls the glucose level in blood. If pancreas does not produce the required amount of insulin, the level of glucose in blood rises. This condition is known as diabetes mellitus in human. Diabetic patients need regular injections of insulin to control glucose level in the blood. In past, insulin was extracted from the pancreas of animals. Nowadays, genetic engineers produce insulin by inserting its gene in bacteria.



Figure 4.4: Insulin

Vaccines

Vaccine is a material which contains weakened or killed pathogens (disease causing germs) and is used to produce immunity (resistance) against a disease. When a vaccine is injected into the human body, the blood cells in the body take the weak or dead pathogens as real ones and prepare antibodies against them. These antibodies remain in blood. When any real pathogen enters the body, the already present antibodies kill it immediately and the body becomes protected from disease.

Nowadays, biotechnologists use bacteria to prepare vaccines. They identify some proteins of pathogens that do not cause disease but can stimulate blood cells to make antibodies. The gene of such protein is isolated from pathogen and is inserted into bacterium. The GM bacteria make colonies and prepare the pathogen proteins. These proteins act as vaccine. When these proteins are injected in human body, the blood cells produce antibodies. These antibodies can kill the kind of the pathogen from which the gene was taken. In this way the human becomes safe from that kind of pathogens. Vaccines for COVID-19, hepatitis-B, typhoid, measles, etc., have been developed using biotechnological technique. Vaccines for malaria and HIV are being developed. Other



Figure 4.5: Vaccine

important life saving biotechnology products include blood clotting factors, growth hormones, etc.

4.4 APPLICATIONS OF BIOTECHNOLOGY

Four major areas in which biotechnology is applied include agriculture, food production and preservation, health and environment.

4.4.1 Agriculture

Biotechnology has played a revolutionary role in improving our agriculture and production of high yields of crops (Figure 4.6). Herbicides (weed killing chemicals) and pesticides (insect killing chemicals) are used to eliminate the crop enemies (weeds and insects). Such chemicals also cause damage to the crop plants. Using biotechnology, scientists insert weed resistance and pest resistance genes into the plants. Such genetically modified plants prepare proteins which are harmful for weeds and pest /insects.

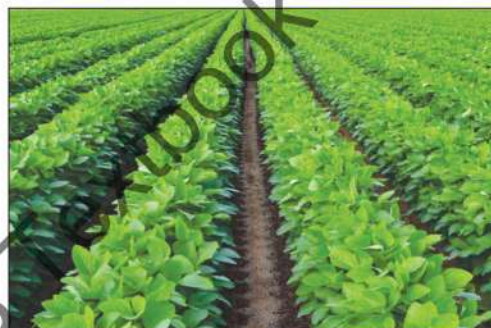


Figure 4.6 High yield crop

Cultivation of such genetically modified crops improves the yields of the crops and makes them safe for human use. The major crops that have been modified are maize (corn), wheat, rice, canola, potato, soybean, cotton, etc. Drought and excessive salts in the soil also have harmful effects on crop productivity. Biotechnologists are working to find genes that can enable crops to tolerate such extreme conditions. Scientists in some universities have introduced a gene to raise iron content in rice and wheat. This may help to overcome iron deficiency in food. In Pakistan many biotech crops such as wheat, rice and potato have been developed.

You need to know!

- In poor countries of South Asia, where rice is the main food of the rural population, deficiency of vitamin A is the common problem which may lead to early blindness and weak immune system especially in children. Scientists have successfully transferred genes of vitamin A from other species into rice, creating a variety of rice rich in vitamin A. Genetically modified golden rice is produced by genetic engineering.



Genetically modified golden rice

- Most of the high yield crops or fruit trees are susceptible to diseases. Introduction of disease resistance genes into such crops or fruit trees enables them to resist diseases.
- Insects called aphids damage the wheat crop. This problem can be solved by producing aphid resistant varieties using genetic engineering techniques.

4.4.2 Food Production and Preservation

Use of better quality genes in the animals is producing high yields of milk and meat (Figure 4.7).



You need to know.

Vitamin B12, widely used as an additive in food and in some medicines, is produced in high-yielding cultures of bacteria.



Milk producing animal



Meat producing animals



Goat meat

Figure 4.7 Genetically modified animals and animal product

Production of better quality fruits and vegetables and increasing their shelf lives are also due to using biotechnological techniques (Figure 4.8).



Better quality fruit



Vegetables

Figure 4.8 : Genetically modified fruits and vegetables

4.4.3 Health

Biotechnology techniques are also used for curing diseases and improving health. The diseases for which previously no adequate treatment was available can now be treated using biotechnology techniques. Identification of root causes of diseases, production of medicines for fighting against diseases, curing and correction of genetic defects, etc., are the major roles of this technology in developing better health. Various biotechnology products which are used in Pakistan to save lives include:

Insulin:

useful for diabetics

Vaccines:

used against many infectious diseases

Growth hormone:

useful for stimulating growth

Beta-Endorphin:

a pain killer drug

Interferon:

anti-viral proteins

4.4.4 Environment

Environmental problems, like pollution, degradation of land and sewage water, etc., are also resolved using biotechnology. Microorganisms, e.g., genetically modified bacteria are used to treat sewage and refuse. They may also be used to clear spilled oil. Microbes which are used as bio-pesticides, bio-fertilizers, biosensors, etc., are being developed using biotechnology techniques.

Science, Technology, Society and Environment

Biotechnologists have identified a gene in weed plant which enables the plant to show tolerance to salts, drought, heat and cold. In a research project; when this gene was inserted into tomato and tobacco cells, they withstood the said adverse conditions far better than ordinary cells. If these preliminary results prove successful in larger trials, then this gene can help in producing crops which can better withstand the unfavourable conditions.

Various research institutes in Pakistan conduct genetic engineering on humans, livestock and crop plants e.g., National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad; National Centre of Excellence in Molecular Biology (CEMB), University of the Punjab, Lahore; Centre for Advanced Studies (CAS), University of Agriculture, Faisalabad; Nuclear Institute for Agriculture & Biology (NIAB), Faisalabad; and Pakistan Council of Scientific and Industrial Research (PCSIR), Islamabad.

KEY POINTS

- The technology in which living things are used in different ways to help and benefit human beings is called biotechnology.
- The special parts of DNA having information for making specific proteins are called genes. Genes are located on chromosomes.
- Genetic engineering is a biotechnological technique by which a particular gene is cut and transferred from one type of organism to another organism such as bacterium.
- The attached gene of desired protein and the plasmid DNA are collectively called recombinant DNA.
- The bacterium which takes in the recombinant DNA is called genetically modified bacterium (GM bacterium).
- Bacteria which are genetically modified with human insulin gene produce human insulin which control the glucose level in blood.
- Nowadays, vaccines produced by genetic engineering are used against the diseases like Hepatitis B (a human disease), foot and mouth disease (a viral disease in cattle, goat and sheep, etc.) and many other diseases.
- Biotechnology has played a revolutionary role in improving our agriculture and livestock. Production of high yield of crops, milk and meat are the results of using biotechnology.
- Biotechnology is also used for resolving environmental problems, like pollution, degradation of land and sewage water, etc.

QUESTIONS

1. Encircle the correct option.

- (i) The additional circular pieces of DNA present in a bacterial cell are called:
(a) RNA (b) nucleotides
(c) chromatids (d) plasmids
- (ii) What may be the objective of genetic modifications of plants?
(a) Production of disease resistant plants
(b) Improvement in nutritional quality of plants
(c) Production of herbicide resistant plants
(d) All of these
- (iii) Plasmid and attached foreign gene with it are collectively called:
(a) recombinant cell (b) recombinant DNA
(c) recombinant plasmid (d) recombinant chromosome
- (iv) The organisms whose cells and plasmids are usually used in genetic engineering are:
(a) bacteria (b) fungi
(c) algae (d) viruses
- (v) Sections of DNA serving as codes for developing characters in an organism are called:
(a) genes (b) nucleotides
(c) plasmids (d) proteins
- (vi) Which of the following is not a biotechnology product?
(a) Insulin (b) Quinine
(c) Beta-endorphin (d) Interferon
- (vii) How do genetic engineers get insulin for diabetic patients?
(a) Isolate from human pancreas
(b) Isolate from pancreas of other animals
(c) Insulin gene inserted in human pancreas
(d) Insulin gene inserted in bacteria
- (viii) Why do genetic engineers use bacteria in genetic engineering?
(a) The chromosome of bacteria is made of DNA and proteins
(b) Their nucleus is very big and easy to handle
(c) They have many chromosomes
(d) Bacteria divide very fast and make colonies

(ix) A gene is inserted into a bacterium by:

- (a) tissue culture (b) fermentation
(c) biodegradation (d) genetic engineering

2. Write short answers.

- (i) What is biotechnology?
(ii) Name at least two life saving products of biotechnology.
(iii) Write the application of biotechnology in
(a) agriculture (b) health (c) food production

3. Constructed response questions

- (i) How can biotechnology be helpful in agriculture?
(ii) Find out which biotechnological products you are using in your daily life.

4. Investigate

- (i) Find out in the history where pandemic was controlled by vaccines.
(ii) Investigate how the biotechnology has brought revolution in the field of health.

Project

Conduct a research in the supervision of your teacher to explore the outcomes of scientists in the field of biotechnology.

	Name of the scientist	Contribution
Used biotechnology in the field of food production.		
Used biotechnology in the field of medicine.		
Used biotechnology in the field of agriculture.		