Chapter 3

# BIOTECHNOLOGY

## STUDENTS' LEARNING OUTCOMES

**After studying this chapter, students will be able to:**

- ☑ Define biotechnology.
- ☑ Explain how DNA is replicated.
- ☑ Describe the relationship between DNA, genes and chromosomes.
- ☑ Define bacterium.
- ☑ Explain how genes are introduced into a bacterium.
- ☑ List some biotechnological products used in daily life.
- ☑ Explain that genetic modification in different foods can increase the amount of essential nutrients.
- ☑ List general applications of biotechnology in various fields.
- ☑ Explain how biotechnology allows meeting the nutritional needs of growing populations.

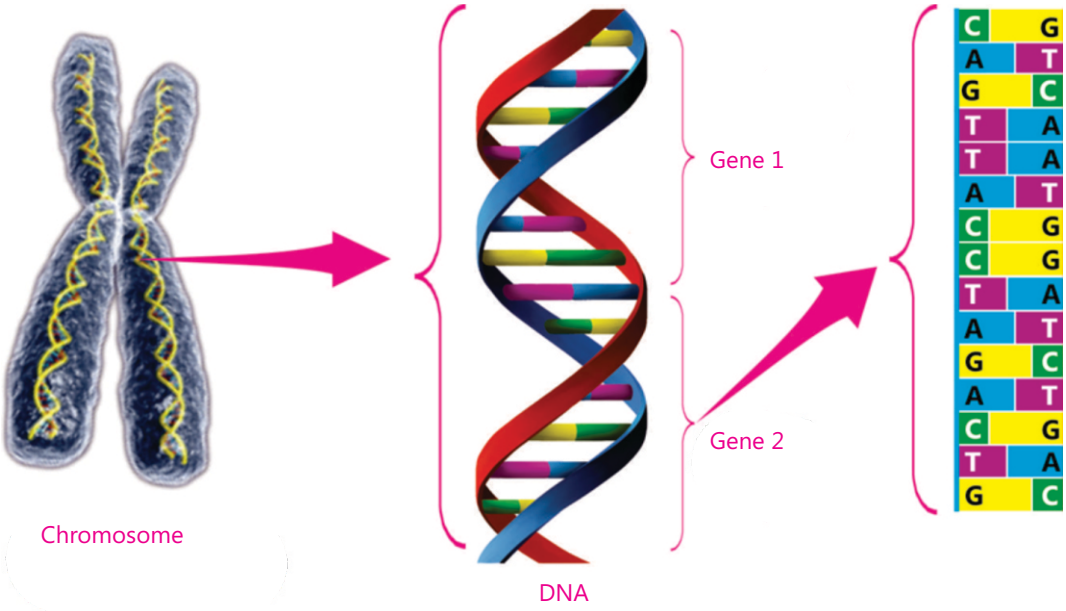
Application of knowledge in the areas like engineering and medicines, etc., is called technology. The technology in which living things are used in different ways to help and benefit human beings is called **biotechnology**. Microorganisms are used in making bread, yogurt, cheese, vinegar and several 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.

**You need to know.**

### Relationship between chromosomes, DNA and genes

As we have learnt in the previous chapter, there is a close structural and functional relationship between, chromosomes, DNA and genes.

- Chromosomes are the thread-like structures found in the nucleus of a cell. They are made up of DNA and proteins.
- DNA is the hereditary material.
- Genes (the sections of DNA) are located on chromosomes and control the development of hereditary characters in an organism.
- In human cells, there are more than one thousand genes on a single chromosome.




Relationship between Chromosome, DNA and Gene

## 3.1 DNA Replication

DNA has a unique property to replicate itself. Replication of DNA is a process by which DNA makes its copy. The process of DNA replication takes place in the nucleus of the cell during interphase.

The first step in DNA replication is unwinding of its double helix structure and separation of two strands from each other like the separation of two strands of an open zipper (Figure 3.1).

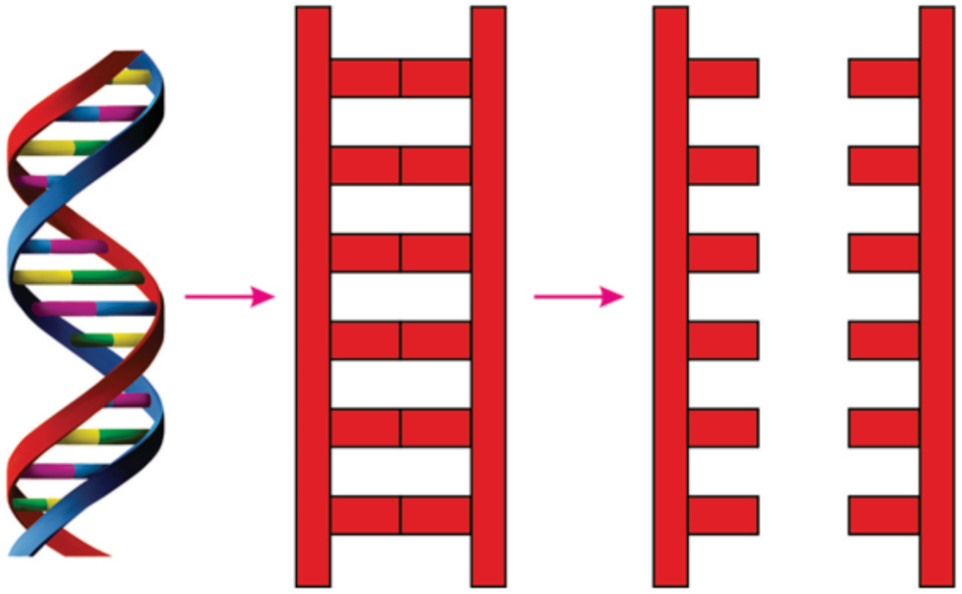


**Figure 3.1:** Unwinding of DNA and separation of two strands

In second step, each of these strands produces a new strand using new nucleotides. In this way, one double strand DNA molecule produces its identical copy and two daughter DNA molecules are formed. Each daughter DNA contains one new strand and one strand of the parent DNA (Figure 3.2).

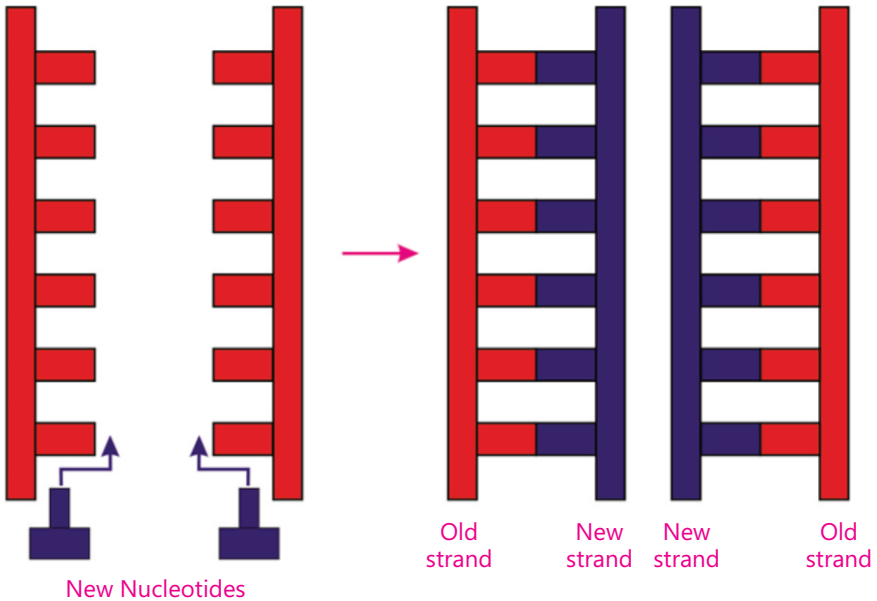



**Figure 3.2:** Replication of DNA

## 3.2 Introduction of Gene into Bacterium

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.

### Why do Scientists use Bacteria in Genetic Engineering?

Bacterial cell 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 3.3).

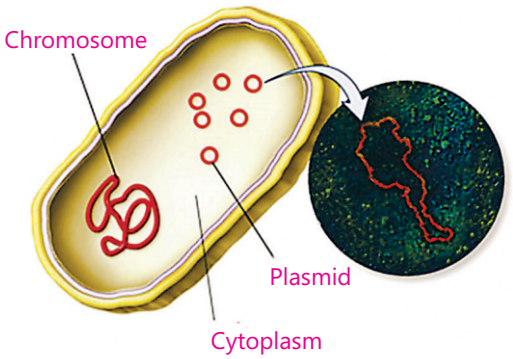



**Figure 3.3:** Bacterial Cell

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.

**? Do you know?**

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

### How do Scientists Insert Gene in a Bacterium?

The first step 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 3.4). 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 3.4).

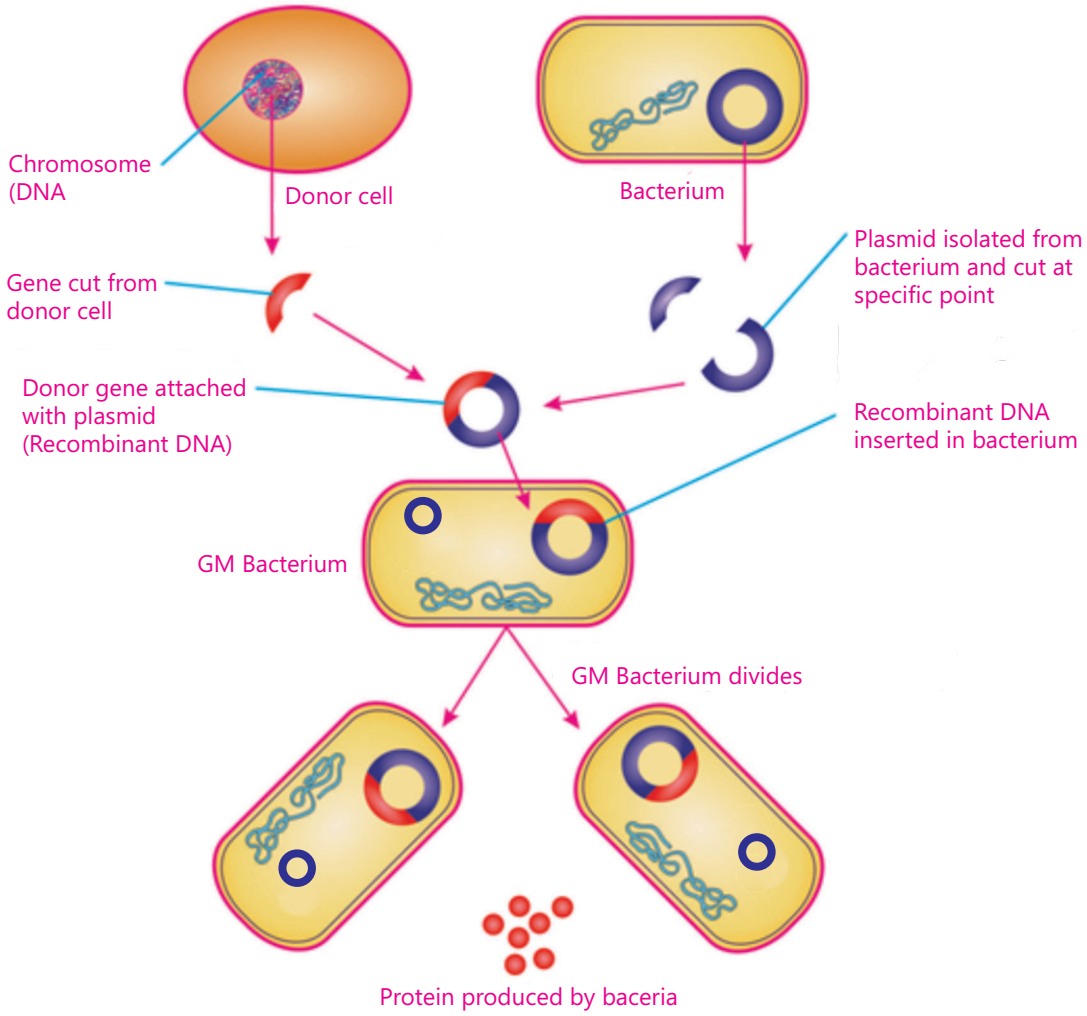



**Figure 3.4:** Introduction of gene into a bacterium

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.

## 3.3 Genetic Modifications and Biotechnology Products

The change in the genes of organisms using biotechnology techniques is called genetic modification. The change in the genes of an organism can be produced by removal, addition or modification of genes. 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 improvement in the nutritional quality of edible plants is also one of the advancements of genetic modification. The organism whose genes are modified is called Genetically Modified Organism (GMO). GMOs are also used to prepare useful and lifesaving products such as insulin and vaccines, etc. (see Figure 3.5).

### 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

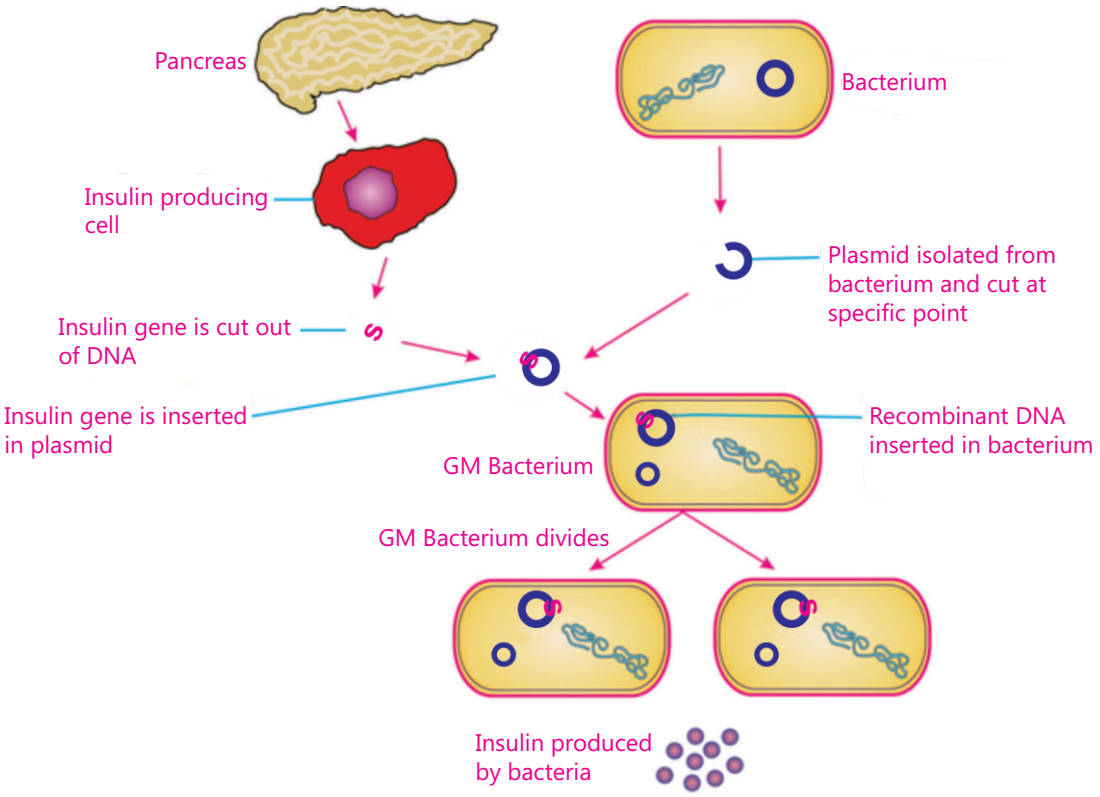



**Figure 3.5:** Production of insulin by genetically modified bacterium

patients need regular injections of insulin to control glucose level in the blood. In past, insulin was extracted from the pancreas of animals. Nowadays, it is produced using biotechnology techniques. Scientists insert the human insulin gene in bacteria to modify them genetically. These genetically modified bacteria (GM bacteria) prepare insulin. The insulin prepared in GM bacteria is extracted from bacterial colonies and used. The steps of biotechnology techniques for the production of insulin are shown in the Figure 3.5.

## 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 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, its 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 hepatitis-B, typhoid, measles, etc., have been developed using biotechnology (Figure 3.6). Vaccines for malaria and HIV are being developed.


**Figure 3.6:** Vaccine for Hepatitis B

Other important lifesaving biotechnology products include blood clotting factors, growth hormones, etc.

## 3.4 Applications of Biotechnology

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

### 3.4.1 Agriculture

Biotechnology has played a revolutionary role in improving our agriculture and production of high yields of crops (Figure 3.7). 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. Cultivation of such genetically modified crops improves the quality 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.

**Figure 3.7:** High yield crop

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.

**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

- Pakistani scientists in some Universities are trying to produce wheat having higher proportion of iron in the flour. This may help overcome iron deficiency in food.

**You need to know.**

- Most of the high yield crops or fruit trees are susceptible to diseases. Introduction of disease resistance genes into such crops or fruit trees enable 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.

## 3.4.2 Food Production and Preservation

Use of better quality genes in the animals is producing high yields of milk and meat (Figure 3.8).

Milk producing animal

Meat producing animals

Goat meat

**Figure 3.8:** Genetically modified animals and animal product

Production of better quality fruits and vegetables and increasing their shelf lives are also due to using biotechnology techniques (Figure 3.9).

Better quality fruit

Vegetables

**Figure 3.9:** Genetically modified fruits and vegetables

**You need to know.**

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

### 3.4.3 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 and curing and correction of genetic defects, etc., are the major roles of this technology in developing better health. Various biotechnology products which are used 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 |

### Important biotechnology techniques

**Gene Therapy**

Gene therapy is an advanced biotechnological technique which is used to cure genetic and acquired diseases like cancer and AIDS. In this process, defective genes are supplemented or replaced by normal genes.

**Genetic Testing**

Genetic testing is one of the latest biotechnological techniques used for genetic diagnosis of inherited diseases. It involves the direct examination of DNA molecule. It is also used to determine a child's paternity or a person's ancestry.

**Cloning**

Cloning is also amongst the latest biotechnological techniques used in various types of genetic analyses. Animal cloning can be used for production of animal organs, and strong, well built livestock for quality production of milk and meat.

### 3.4.4 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.

Gene therapy, genetic testing, cloning, etc., are the examples of biotechnological methods used for treating various diseases.

# 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.
- The process by which DNA makes its copy is called DNA replication.
- The use of biotechnology techniques to change the genes of an organism is called genetic modifications. Genetic modification involves the removal, addition or modification of genes.
- Genetic engineering is a biotechnology 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 yields 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

**3.1 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. fungi and algae

(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) Biotechnological method for the production of animal organs:

a. gene therapy b. genetic testing
c. cloning d. organ transplant

(ix) 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

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

a. tissue culture
b. fermentation
c. biodegradation
d. genetic engineering

3.2 Match the statements of column A with the relevant statements of column B.

| A | B |
|---|---|
| Growth hormone | Viral infection |
| Beta-Endorphin | Diabetes |
| Vaccine | stimulating growth |
| Interferon | Immunity against diseases |
| Insulin | Pain killer |

3.3 Give short answers.

(i) What is biotechnology?
(ii) What is genetic testing?
(iii) Name at least two life saving products of biotechnology.
(iv) Briefly describe gene therapy.

3.4 How do scientists insert the gene of a desirable protein into a bacterium?

3.5 Give diagrammatic explanation of biotechnological process for the preparation of insulin.

36. Describe the application of biotechnology in agriculture.

3.7 What is genetic modification? How is it helpful in increasing the amounts of different nutrients in food?

3.8 Describe the application of biotechnology in health and environment.

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