CHAPTER 17

BIOTECHNOLOGY

MULTIPLE CHOICE QUESTIONS

(1) **The use of living organisms in process for the manufacture of useful products:**
(a) Parasitology (b) Biotechnology (c) Pharmacology (d) Drug abuse

(2) **When the work on genetic engineering started?**
(a) 1941 (b) 1942 (c) 1943 (d) 1944

(3) **When was human genome project launched?**
(a) 1990 (b) 1991 (c) 1992 (d) 1993

(4) **What was the name of sheep produced by Ian Wilmut from the body cell of an adult sheep?**
(a) Dolly (b) Nancy (c) Ethal (d) Dhani

(5) **Ian Wilmut belonged to**
(a) Newzealand (b) Australia (c) Scotland (d) America

(6) **An antiviral protein:**
(a) Insulin (b) Thymosin (c) HGH (d) Interferon

(7) **Insulin is a:**
(a) Hormone (b) Antiseptic (c) Antifungal (d) Sedative

(8) **How much yeast is required to produce 250 tons of protein in one day?**
(a) 20 kg (b) 30 kg (c) 40 kg (d) 50 kg

(9) **Who convinced the scientific community that all fermentations are the result of microbial activity?**
(a) Alexander Fleming (b) Joseph Lister (c) Louis Pasteur (d) Edward Jenner

(10) **In glycolysis, the glucose molecule is broken down into two molecules of:**
(a) Acetic acid (b) Lactic acid (c) Pyruvic acid (d) Formic acid

(11) **When milk protein is coagulated, what is formed?**
(a) Yogurt (b) Cheese (c) Alcohol (d) Wine

(12) **The enzymes that are used to cut the identified gene from the DNA of donor organism:**
(a) Restriction endonucleases (b) Ligases
(c) Lipases (d) Amylases

(13) **Diabetes is cured by:**
(a) Human Growth Hormone (b) Insulin
(c) Glucagon (d) Parathormone

(14) **A pain killer produced by brain:**
(a) Thymosin (b) Beta-endorphin
(c) Insulin (d) Human Growth Hormone

(15) **How many sheep brains are required to produce 1 mg human growth hormone:**
(a) 10,000 (b) 1,000 (c) 100,000 (d) 1,000,000

ANSWER KEY

Q.No.	Ans	Q.No.	Ans	Q.No.	Ans	Q.No.	Ans	Q.No.	Ans
1	b	2	d	3	a	4	a	5	c
6	d	7	a	8	d	9	c	10	c
11	b	12	a	13	b	14	b	15	c

SHORT QUESTIONS

Q. No. 1 Till how long the humans are using biotechnology?

USE OF BIOTECHNOLOGY

Humans have been making use of biotechnology since they discovered farming. This use extended from the planting of seeds to the control of plant growth and crop production.

Examples:

- Animal breeding is also a form of biotechnology.
- Cross-pollination of plants and cross-breeding of animals were major techniques in biotechnology.

Q. No. 2 Why Cross-pollination and cross-breeding techniques were used?

USAGE OF TECHNIQUES

Cross-pollination of plants and cross-breeding of animals were major techniques in biotechnology used to:

- Enhance product quality
- Meet specific requirements

Q. No. 3 What is old biotechnology?

OLD BIOTECHNOLOGY

Although the term biotechnology is new, the discipline itself is very old. Fermentation and other such processes, which are based on the natural capabilities of organisms, are commonly considered as old biotechnology.

Q. No. 4 Define biotechnology.

BIOTECHNOLOGY

The use of living organisms in processes for the manufacture of useful products or for services is called biotechnology.

Q. No. 5 When human being started use of microorganisms?

USE OF MICROORGANISMS

Human began using microorganisms as early as 4000 BC for making:

- Wine
- Vinegar
- Cheese
- Yogurt

Some of these processes have become a part of every home that we may even hesitate to refer them as biotechnology.

Q. No. 6 What do you know about Dolly Sheep?

DOLLY SHEEP

In Scotland, in 1997, an embryologist Ian Wilmut produced a sheep (Dolly) from the body cell of an adult sheep.

Q. No. 7 What is the difference between cellular respiration and fermentation?

DIFFERENCE BETWEEN CELLULAR RESPIRATION AND FERMENTATION

Cellular Respiration	Fermentation
In cellular respiration, glucose molecule goes through oxidation-reduction reactions to release energy in the form of ATP.	The process in which there is incomplete oxidation-reduction of glucose is called fermentation.

Q. No. 8 What are the fears related to biotechnology?

FEARS RELATED TO BIOTECHNOLOGY

Fears are also being expressed about the advances in biotechnology in terms of release of harmful organisms developed through recombinant DNA technology.

Q. No. 9 What is the role of Louis Pasteur in fermentation?

ROLE OF LOUIS PASTEUR IN FERMENTATION

In 1857, Pasteur convinced the scientific community that all fermentations are the results of microbial activity. He showed that fermentation is always accompanied by the development of microorganisms. There are many kinds of fermentation and each kind is a characteristic of particular microbial group.

Q. No. 10 How are the fermentations classified?

CLASSIFICATION OF FERMENTATIONS

Fermentations are classified in terms of the products formed.

Q. No. 11 What are the steps of carbohydrate fermentation?

STEPS OF CARBOHYDRATE FERMENTATION

The initial steps of carbohydrate fermentation are identical to those of respiration. The process begins with glycolysis, in which the glucose, molecule is broken into two molecules of pyruvic acid. Different microorganisms proceed the further reactions in different ways. It results in the formation of various products from pyruvic acid.

Q. No. 12 Before genetic engineering, how many sheep brains were required to produce 5 mg of human growth hormone?

REQUIREMENT OF SHEEP BRAINS

Before genetic engineering, 500,000 sheep brains were required to produce 5 mg of human growth hormone.

Q. No. 13 Why single cell proteins are called so?

NAMING OF SINGLE CELL PROTEIN

The single cell proteins are called so because the microorganisms used as producers are unicellular or filamentous individuals.

LONG QUESTIONS

Q. No. 1 Write a note on genetic engineering.

GENETIC ENGINEERING

Introduction:

It deals with the following aspects of genetic material (DNA):

- Artificial synthesis
- Modification
- Removal
- Addition
- Repair

Modern Biotechnology:

It is considered as modern biotechnology.

Need:

It is done to alter the characteristics of organisms.

Work Done on DNA:

The work on genetic engineering started in 1944 when it was proved that DNA carries the genetic information. Scientists isolated the enzymes of DNA synthesis and then prepared DNA outside cells. In 1970s, they were able to cut and paste the DNA of organisms.

Preparation of Insulin:

In 1978, scientists prepared human insulin by inserting the insulin gene in bacteria.

Preparation of Human Growth Hormone:

Human growth hormone was also synthesized in bacteria.

Human Genome Project:

In 1990, the Human Genome Project was launched to map all the genes in human cell. The complete map of human genome was published in 2002.

Q. No. 2 Explain the scope and importance of biotechnology.

BIOTECHNOLOGY

The use of living organisms in processes for the manufacture of useful products or for services is called biotechnology.

SCOPE AND IMPORTANCE OF BIOTECHNOLOGY

In recent years, biotechnology is growing as a separate science. It has attracted the attention of many intellectuals from diverse fields like:

- Agriculture
- Medicine
- Microbiology
- Organic chemistry

The scope for biotechnology is so wide that it is difficult to recognize the limits. The following are some areas of the application of biotechnology:

Biotechnology in the Field of Medicine:

In the field of medicine, biotechnologists have synthesized:

- Insulin
- Interferon, an antiviral protein
- Vaccines
- Antibodies
- Human Growth Hormone

Enzymes:
Various enzymes are being synthesized for medicinal as well as industrial use.

Gene Therapy:
Gene therapy (treatment through genes) has become important in recent years.

Forensic Medicine:
Biotechnology also proved much beneficial in forensic medicine.

Identification of Criminals:
The study of DNA helps in the identification of criminals.

Biotechnology in the Field of Food and Agriculture:

Food Industry:
The following products are being produced by using microorganisms:

- Fermented foods (e.g. pickles, yogurt)
- Malted foods (e.g. powdered milk: a mixture of barley, wheat flour and whole milk)
- Various vitamins
- Dairy products

Beverage Industry:
Wine and beer are produced in beverage industry.

Agriculture:
Biotechnology has also revolutionized research activities in the area of agriculture.

Transgenic Organisms:
The organisms with modified genetic set-up are called transgenic organisms.

Transgenic Plants:
Transgenic Plants: plants are being developed in which desirable characteristics are present:

- More yields
- Resistance against diseases
- Resistant against insects
- Resistant against herbicides

Transgenic Animals:

- Transgenic goats, chickens, cows give more food and milk.
- Many animals like mice, goats, cows etc. have been made transgenic to get medicines through their milk, blood or urine.

Biotechnology and Environment:
Biotechnology is also being used for dealing with environmental issues like:

- Pollution control
- Development of renewable sources for energy
- Restoration of degraded lands
- Biodiversity conservation

Treatment of Sewage Water:
Bacterial enzymes are used to treat sewage water to purify.

Use of Microbes:
Microbes are being developed to be used as biopesticides, biofertilizers, biosensors etc.

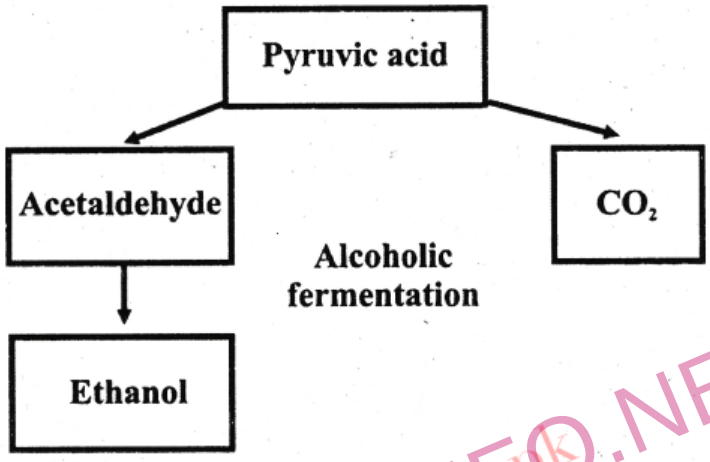
Other Purposes:
Such transgenic microorganisms are also used for:

- Recovery of metals
- Cleaning of spilled oils

Usage:

This process is quite important and is used to produce:

- Bread
- Beer
- Wine
- Distilled spirits



2. Lactic Acid Fermentation (by bacteria):

Mechanism:

In this process, pyruvic acid is reduced to lactic acid.

Organisms Involved:

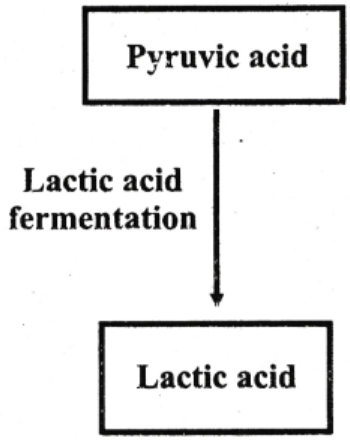
It is carried out by many bacterial species like:

- *Streptococcus*
- *Lactobacillus*

Usage:

It is quite important in dairy industry where it is used for:

- Souring milk
- Production of various types of cheese



Q. No. 4 Write a note on applications of fermentation.

APPLICATIONS OF FERMENTATION

In fermentation, maximum growth of an organism is obtained for the production of desired products of commercial value. Traditionally, only food and beverage products were produced by using fermentation. Now many other products e.g. industrial chemicals are also being produced.

This can be categorized into two groups:

1. Fermented Foods
2. Industrial Products

1. Fermented Foods:

Fermentation often makes the food more nutritious, more digestible and tastier. It also tends to preserve the food, lowering the need for refrigeration. The following groups are included in the fermented foods.

(i) Cereal Products:

Bread is the commonest type of fermented cereal product. Wheat dough is fermented by *S. cerevisiae* along with some lactic acid bacteria.

(ii) Dairy Products:

Cheese and yogurt are important fermentation products.

Cheese Formation:

Cheese is formed when a milk protein is coagulated. This happens when the acid produced by lactic acid bacteria reacts with milk protein.

Yogurt Formation:

Yogurt is made from milk by different lactic acid bacteria.

(iii) Fruit and Vegetable Products:

Fermentation is usually used, along with salt and acid, to preserve:

- Pickle
- Fruits
- Vegetables

(iv) Beverage Products:

Beer is produced from cereal grains which have been malted, dried and ground into find powder. Fermentation of the powder is done by yeast. This process breaks the glucose present in powder into pyruvic acid and then into ethanol. Grapes can be directly fermented by yeasts to wine.

Q. No. 3 Define fermentation. What is carbohydrate fermentation? Explain its types.

FERMENTATION

Definition:

The process in which there is incomplete oxidation-reduction of glucose is called fermentation.

History:

Fermentation has been in the knowledge of man since centuries, but it was believed that it is purely a chemical process.

Carbohydrate Fermentation:

The initial steps of carbohydrate fermentation are identical to those of respiration. The process begins with glycolysis, in which the glucose, molecule is broken into two molecules of pyruvic acid. Different microorganisms proceed the further reactions in different ways. It results in the formation of various products from pyruvic acid.

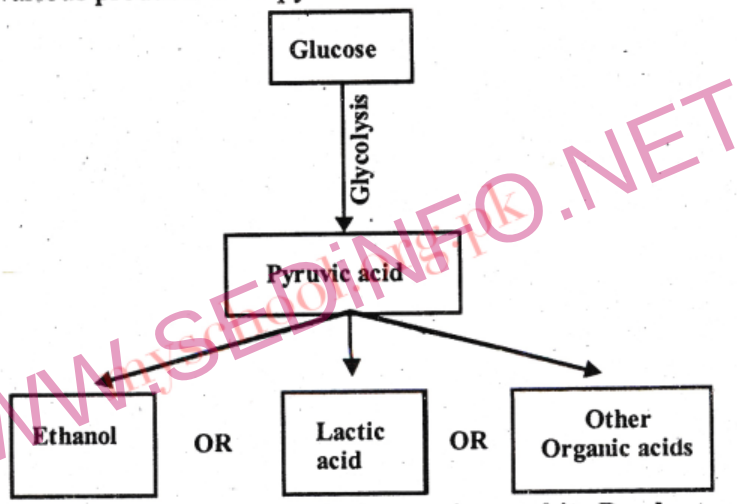


Figure: Carbohydrate Fermentation and its Products

TYPES OF CARBOHYDRATE FERMENTATION

The two basic types of carbohydrate fermentation are as follow:

1. Alcoholic Fermentation (by yeast)
2. Lactic Acid Fermentation (by bacteria)

1. Alcoholic Fermentation (by yeast):

Organism Involved:

This fermentation is carried out by many types of yeast such as *Saccharomyces cerevisiae.*

Mechanism:

In this process, carbon dioxide is removed from pyruvic acid. The product i.e. acetaldehyde is then reduced to ethanol. The carbon dioxide produced during this fermentation causes the rise of the bread.

2. Industrial Products:

The following are the important industrial products produced through the process of fermentation.

Products	Microorganisms Used	Some Uses
Formic acid	*Aspergillus*	• Textile dyeing • Leather treatment • Eelectroplating • Rrubber manufacture
Ethanol	*Saccharomyces*	• Used as solvent • Production of vinegar • Production of beverages.
Glycerol	*Saccharomyces*	• Used as solvent • Production of plastics • Production of cosmetics • Production of soaps • Used in printing • Used as sweetener
Acrylic Acid	*Bacillus*	• Used in the production of plastics

Q. No. 5 What is a fermenter? Describe types of fermentation. What are the advantages of using fermenters?

FERMENTER

Fermenter is a device that provides optimum environment to microorganisms to grow into a biomass, so that they can interact with a substrate, forming the product.

Heart of Industry:

In fact, the fermenter constitutes the heart of any industrial fermentation process.

TYPES OF FERMENTATION:

Fermentation is carried out in fermenters, in the following two ways.

1. Batch Fermentation
2. Continuous Fermentation

1. Batch Fermentation:

In this process, the tank of fermenter is filled with the raw materials to be fermented. The temperature and pH for microbial fermentation is properly adjusted, and nutritive supplements are added. All the material is steam sterilized, the pure culture of microorganisms is added to fermenter from a separate vessel. Fermentation proceeds and after the proper time the contents of fermenter are taken out. Fermenter is cleaned and the process is repeated. Thus, fermentation is a discontinuous process divided into batches.

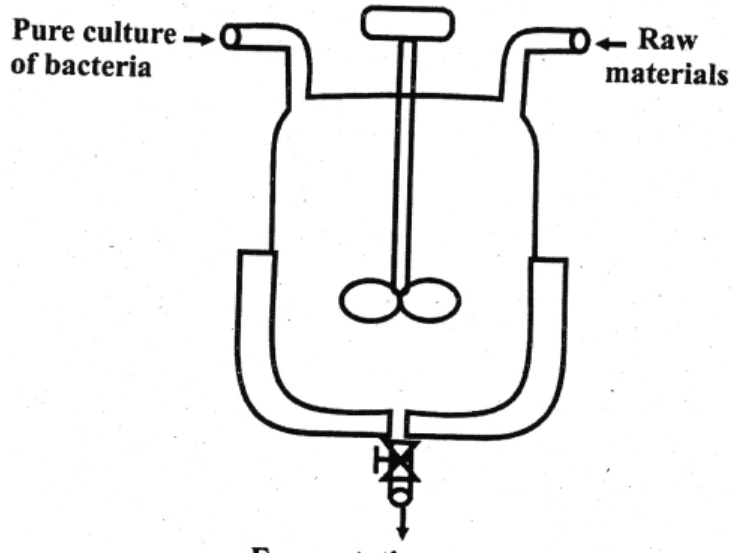


Figure: A Batch Fermenter

2. Continuous Fermentation:

In this process, the substrate is added to fermenter continuously at a fixed rate. This maintains the microorganisms in growth phase. Fermentation products are taken out continuously.

The design and arrangements for continuous fermentation are more complex.

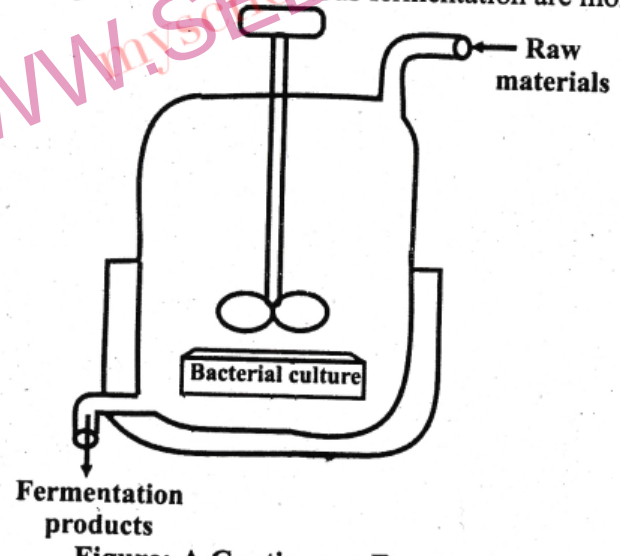


Figure: A Continuous Fermenter

ADVANTAGES OF USING FERMENTERS

Controlled Environment:

For each biotechnological process, the environment provided to the organisms must be monitored and controlled. Such a controlled environment is provided by fermenters.

Controlling Different Factors:

A fermenter optimizes the growth of the organisms by controlling many factors like:

- Nutrients
- Oxygen
- Growth inhibitors
- pH
- Temperature

Capacity:

A fermenter may hold several thousand liters of the growth medium. So, fermenters allow the production of materials in bulk quantities. Massive amounts of the following products are being produced in fermenters:

- Medicines
- Insulin
- Human growth hormone
- Proteins

Inexpensive:

This production proves much inexpensive.

Q. No. 6 What is genetic engineering? What are its objectives?

GENETIC ENGINEERING

Introduction:

Genetic engineering or recombinant DNA technology involves the artificial synthesis, modification, removal, addition and repair of the genetic material (DNA).

Development:

Genetic engineering developed in the mid-1970s when it became possible to cut DNA and to transfer particular pieces of DNA from one type of organism into another. As a result, the characteristics of the host organism could be changed. If host organism is a microorganism, such as a bacterium, the transferred DNA is multiplied many times as the microorganism multiplies. Consequently, it is possible to obtain millions of copies of a specific DNA inside a bacterial cell.

OBJECTIVES OF GENETIC ENGINEERING

The important objectives of genetic engineering are as follows:

Gene Therapy:

Isolation of a particular gene or part of a gene for various purposes such as gene therapy

RNA and Proteins:

Production of particular RNA and protein molecules

Production Improvement:

Improvement in the production of enzymes, drugs and commercially important organic chemicals

Plant Varieties:

Production of varieties of plants having particular desirable characteristics

Treatment Purposes:

Treatment of genetic defects in higher organisms

Q. No. 7 Describe the process of genetic engineering.

GENETIC ENGINEERING

The following basic steps are involved in genetic engineering:

Isolation of the Gene of Interest:

In the first step, the genetic engineer identifies the gene of interest in a donor organism. Special enzymes, called restriction endonucleases, are used to cut the identified gene from the total DNA of donor organism.

Insertion of the Gene into a Vector:

A vector is selected for the transfer of the isolated gene of interest to the host cell. The vector may be a plasmid (the extra-chromosomal DNA present in many bacteria) or a bacteriophage. The gene of interest is attached with the vector DNA by using endonuclease (breaking enzymes) and ligase {Joining enzymes).

Formation of Recombinant DNA:

The vector DNA and the attached gene of interest are collectively called recombinant DNA.

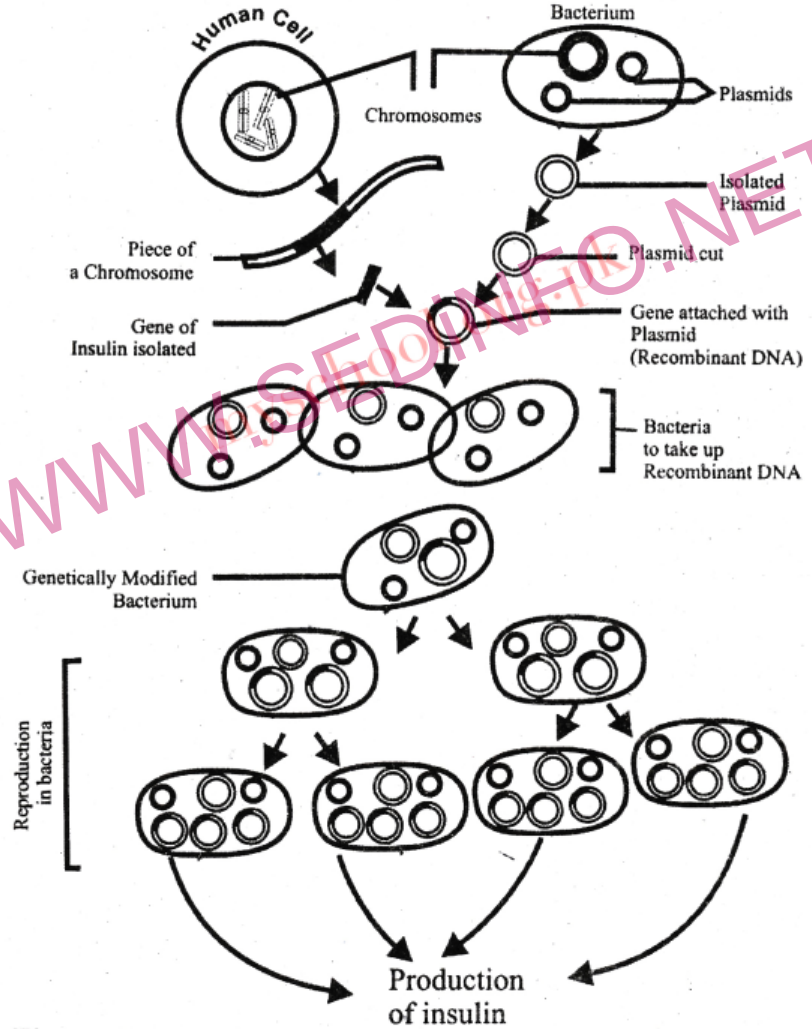


Figure: Production of Insulin through Genetic Engineering

Transfer of Recombinant DNA into Host Organism:

Recombinant DNA is transferred to the target host. In this way, host organism is transformed into a genetically modified organism (GMO).

Growth of the GMO:

The GMO are provided suitable culture medium for growth to give as much copies of the gene of interest as needed.

Expression of the Gene:

The GMO contains the gene of interest and manufactures the desired product, which is isolated from culture medium.

Q. No. 8 Describe the achievements of genetic engineering.

ACHIEVEMENTS OF GENETIC ENGINEERING

Various achievements of genetic engineering are as follows.

Preparation of Insulin:

Human insulin gene was transferred into bacteria. The genetically modified bacteria became able to synthesize insulin. Diabetics are now receiving this insulin. The steps of genetic engineering for the production of insulin are shown in the following figure:

Preparation of Human Growth Hormone:

In 1977 an *E. coli* bacterium was created that was capable of synthesizing the human growth hormone.

Preparation of Thymosin:

The hormone thymosin which may prove effective against brain and lung cancer has been produced by genetically modified microorganisms.

Preparation of Beta-endorphin:

Beta-endorphin, a pain killer produced by the brain, has also been produced by genetic engineering techniques.

Preparation of Vaccines:

Genetic engineers produced a safe vaccine against the foot and mouth disease (a viral disease in cattle, goats and deer). Similarly many vaccines have been produced against human diseases such as hepatitis B.

Preparation of Interferons:

Interferons are anti-viral proteins produced by cells infected with viruses. In 1980 interferon was produced in the genetically modified microorganisms, for the first time.

Preparation of Urokinase:

The enzyme urokinase, which is used to dissolve blood clots, has been produced by genetically modified microorganisms.

Eliminating Inherited Diseases:

It has become possible to modify the genes in the human egg cell. This can lead to the elimination of inherited diseases like haemophilia.

Cure of Blood Diseases:

Genetic engineering techniques can also be used to cure blood diseases like thalassemia and sickle-cell anaemia, which result from defects in single genes. Normal genes could be transferred into the bone marrow.

Algae:

Algae grown in ponds produce 20 tons (dry weight) of protein per acre/year. This yield of protein is 10-15 times higher than soybeans and 20-50 times higher than corn.

High Vitamin Contents:

When single-cell proteins are produced by using yeasts, the products also contain high vitamin content.

Usage of Wastes:

In the production of single- cell proteins, industrial wastes are used as raw materials for microorganisms. It helps in controlling pollution.

Availability of all Amino Acids:

The use of single-cell proteins has good prospects in future because they contain all essential amino acids.

Seasonal Variations:

The production of single-cell proteins is independent of seasonal variations.

Limited Land Area:

SCP is gaining popularity day by day because it requires limited land area for production.

MULTIPLE CHOICE QUESTIONS

1. Find the correct match for the fermentation product and the organism involved.

(a) Formic acid - *Saccharomyces*
(b) Ethanol - *Saccharomyces*
(c) Ethanol - *Aspergillus*
(d) Glycerol - *Aspergillus*

2. Which one is NOT an objective of genetic engineering?

(a) Production of cheese and yogurt by lactic acid bacteria
(b) Isolation of a particular gene or part of a gene
(c) Production of RNA and protein molecules
(d) Correction of genetic defects in higher organisms

3. Which of these is an anti-viral protein?

(a) Urokinase (b) Thymosin
(c) Insulin (d) Interferon

4. The first step in genetic engineering is;

(a) Growth of the genetically modified organism
(b) Transfer of the Recombinant DNA into the host organism
(c) Isolation of the gene of interest
(d) Insertion of a gene into a vector

ANSWER KEY

Q.No.	Ans	Q.No.	Ans	Q.No.	Ans	Q.No.	Ans
1	b	2	a	3	d	4	c

SHORT QUESTIONS

1. How would you define fermentation with reference to biotechnology?

Consult Long Question No. 3

2. Name any two industrial products made by fermentation. Also describe their uses in the industry.

Consult Long Question No. 4

3. What are the products of the two types of carbohydrate fermentation?

Consult Long Question No. 3

4. Give an example how biotechnology is helping for better environment.

Consult Long Question No. 2

5. In biotechnology, what is meant by Genetically Modified Organism (GMO)? How is it made?

Consult Long Question No. 7

UNDERSTANDING THE CONCEPT

1. Define biotechnology and describe its importance.

Consult Long Question No. 2

2. What is a fermenter? What are the two types of fermentation carried out in fermenters?

Consult Long Question No. 5

3. Describe the achievements of genetic engineering in medicine, agriculture and environment.

Consult Long Question No. 8

4. What basic steps a genetic engineer adopts during the manipulation of genes?

Consult Long Question No. 7

5. What are single cell proteins? Describe their importance.

Consult Long Question No. 9

THE TERMS TO KNOW

Batch fermentation:

The discontinuous fermentation process, divided into batches

Biotechnology:

The use of living organisms in systems or processes for the manufacture of useful products or for services for mankind

Nitrogen Fixation:

Genetic engineers have developed plants that can fix nitrogen directly from the atmosphere. Such plants need less fertilizers.

Q. No. 9 Write a note on single cell proteins.

SINGLE-CELL PROTEIN

Introduction:

This technique was introduced by Prof. Scrimshow of Massachusetts Institute of Technology.

Naming:

It is known as single cell protein because the microorganisms used as producers are unicellular or filamentous individuals.

Explanation:

Single-Cell Protein (SCP) refers to the protein content extracted from pure or mixed cultures of algae, yeasts, fungi or bacteria.

Fermenters:

For the production of single-cell proteins, the microorganisms are grown in fermenters.

Substrates:

These microorganisms utilize a variety of substrates like:

- Agricultural wastes
- Industrial wastes
- Natural gas like methane

Growth of Microorganisms:

Microorganisms grow very vigorously and produce a high yield of protein. The protein content produced by microorganisms is also known as novel protein or minifood.

Need:

Due to over-population, the world is facing the problem of food shortage. In future, the conventional agricultural methods might not be able to provide a sufficient supply of food (especially proteins). For a better management of food shortage problems (in humans and domestic animals), the use of microbes as the producers of single-cell proteins has been successful on experimental basis.

Belief of Scientists:

Scientist and food technologists believe that single-cell proteins will substitute the other protein-rich foods in human and animal feeds.

Significance:

All scientists recognize the significance of the production of single-cell proteins. The microorganisms grow very vigorously and produce a high yield.

Yeast:

It has been calculated that 50 kilogram of yeast produces about 250 tons of protein within 24 hours.

Continuous fermentation:

The fermentation in which substrate is added to the fermenter continuously, at a fixed rate

Fermentation:

The process in which there is an incomplete oxidation-reduction of the organic substrate

Fermenter:

A device that provides optimum environment in which organisms can grow to produce biomass and to form the product

Genetically Modified Organism:

The organism in which DNA (gene) from some other organism has been transferred

Recombinant DNA:

The vector DNA and the attached gene of interest

Restriction endonucleases:

Enzymes used to cut the gene from the total DNA of the organism

Single-Cell Protein:

The protein contents extracted from pure or mixed cultures of algae, yeast, fungi or bacteria; the micro-organisms are grown in fermenters where they produce a high yield of protein

Transgenic:

Organisms with modified genome (genetic make-up)

Vector:

The DNA (plasmid) or bacteriophage that transfers the isolated gene of interest to the host cells