

# Biotechnology and its Applications

**Biotechnology** involves the use of microbes, plants, animals, and their metabolic processes to produce biological products like biopharmaceuticals. **Recombinant DNA Technology (RDT)** has made this possible by allowing the manipulation of genes in various living species to obtain desirable products on a large scale.

The key research areas in biotechnology include finding the best catalyst, which is usually a microbe or a pure enzyme, and creating optimal conditions through engineering for the catalyst to function. The downstream processing technologies are also important for purifying the organic compounds.

## Applications of Biotechnology in Agriculture

Agriculture has greatly benefited from biotechnology applications, particularly in the development of **genetically modified organisms (GMOs)**. While the Green Revolution boosted food production, it did not suffice in feeding the rapidly growing global population. Although agrochemicals and improved farming techniques have helped, they can have negative environmental impacts, and organic farming can be costly for farmers.

GMOs provide a solution to these challenges. They are organisms, such as plants, bacteria, fungi, and animals, whose genes have been manipulated to express one or more foreign genes, known as transgenes. **GM crops** have undergone various changes, including increased tolerance to abiotic stress, reduced use of pesticides and fertilizers, reduced post-harvest losses, and enhanced nutritional value.

By harnessing the power of biotechnology, *agriculture can increase food production sustainably and cost-effectively, while minimizing the negative environmental impacts of traditional farming practices.*

GM crops are plant species that have been developed through biotechnological methods to possess certain desirable traits. One example of such crops is **Bt crops**, which are designed to be pest-resistant. Bt, short for *Bacillus thuringiensis*, is a type of soil bacterium that produces an antitoxin, also known as Bt toxin, which is toxic to insects.

To create Bt crops, scientists extract the gene that codes for the Bt toxin from the bacterium and transfer it into the plants. This process results in the formation of antitoxin in the plants, making them resistant to pests and eliminating the need for pesticides.

**Bt cotton** is a type of Bt crop where the cry gene, which codes for the Bt toxin, is transferred into the cotton plants. This makes the cotton resistant to bollworms and increases its production. There are different types of cry genes that control different pests, such as cry **IAc** and cry **IIAb** for cotton bollworms and cry **IAb** for corn borers.

Similarly, **Bt brinjal** is another type of Bt crop where the cry gene is inserted into the brinjal plant, preventing Fruit and Shoot Borer (FSB) insects from attacking it.

Overall, Bt crops are an example of how biotechnology can be used to create plants that are resistant to pests and have improved yields.

### **Protecting Plants from Nematode Infection**

Tobacco plants are vulnerable to nematode **Meloidogyne incognita**, which can harm the plant's roots and reduce tobacco production. To combat this, scientists have turned to **RNA interference (RNAi)**, a process present in all eukaryotic organisms that provides **cellular defense**. RNAi involves silencing specific mRNA through complementary dsRNA binding, which prevents mRNA translation.

### **Developing Nutrient-Rich Crop**

- **Golden Rice** is a type of genetically modified rice that contains a significant amount of  **$\beta$ -carotene**, which is a provitamin-A that can convert to vitamin-A.
- The enzyme polygalacturonate is responsible for softening the fruit of tomatoes by degrading the pectin in the cell wall. However, in the transgenic tomato variety called '**Flavr savr**,' the production of polygalacturonate is blocked, resulting in longer-lasting, fresh fruit.

### **Applications of Biotechnology in Medicine**

Biotechnological applications in medicine have had a significant impact on healthcare by enabling the mass production of safe and effective therapeutic drugs. For example, **genetically engineered insulin** has made **insulin** more readily available for the management of adult-onset diabetes. Human insulin is not easily available, and animal insulin can cause allergic reactions in humans. Insulin synthesized for human use needs to undergo processing to remove the inactive polypeptide present in the insulin. **Eli Lilly**, an American company, created DNA sequences corresponding to A and B chains of human insulin and introduced them in plasmids of *E. coli* to produce insulin chains. Chains A and B were produced separately, extracted, and combined by creating **disulphide bonds** to form **human insulin or Humulin**.

Another application of biotechnology in medicine is the production of **vaccines** through genetic engineering. These **vaccines**, called recombinant vaccines, are also known as subunit vaccines or second-generation vaccines, such as vaccines for **hepatitis B** and the **polio** virus. **Gene therapy** is used to correct a genetic disorder by replacing a defective or faulty gene with normal healthy ones. For example, it is used to correct **ADA deficiency** by isolating lymphocytes from the blood or bone marrow of the patient, growing them in a culture outside the body, and introducing a normal functional ADA gene into the cultured lymphocytes, which are then returned to the patient. Gene therapy is also used to prevent **cystic fibrosis, hemophilia, and other genetic disorders**.

**Stem cell technology** is a rapidly developing field that combines the efforts of cell biologists and geneticists for the treatment of malignant and non-malignant cells using stem cells. The potential applications of stem cells include organ and tissue regeneration, bone marrow transplantation, and brain disease treatment. Lastly, for effective treatment of diseases, early diagnosis and understanding of their pathophysiology are crucial. Recombinant DNA technology, **PCR**, and **ELISA** are some of the techniques used for early diagnosis, as conventional methods of diagnosis such as serum and urine analysis do not enable early detection of diseases

### **Transgenic animals**

Transgenic animals are those whose genetic material has been altered by incorporating genes from other species.

Benefits of using transgenic animals include:

- (i) Studying normal physiology and development.
- (ii) Investigating diseases such as **cancer** and **cystic fibrosis**.
- (iii) Producing biologically improved products such as  **$\alpha$ -1-antitrypsin**, which is used to treat **emphysema**, and **Rosie**, the first transgenic cow to produce **lactalbumin-enriched milk** with promising applications in the food industry.
- (iv) Ensuring vaccine safety.
- (v) Conducting chemical safety testing.

**Mice** are the most commonly used organisms for transgenic experiments.

### **Ethical issues in Application of Biotechnology**

Biotechnology applications pose ethical issues that need to be considered. One of the potential risks associated with genetic modification of organisms is the unpredictable results that may occur when such organisms are introduced into an ecosystem. Additionally, the use of genetically modified crops may alter evolutionary patterns. There is also a risk of accidentally creating new infectious agents.

To address the ethical concerns related to biotechnology applications, the Indian government has established the **Genetic Engineering Approval Committee (GEAC)**. This organization is responsible for ensuring the validity of GM research, addressing safety issues, and managing patents, among other responsibilities.

A patent is a legal right granted by a government to an inventor that enables them to prevent others from making commercial use of their invention. When patents are granted for biological entities or products derived from them, they are called **biopatents**. However, the usage and modification of living organisms for public services such as food and medicine have created problems with patents being granted for the same.

**Biopiracy** is a term used to describe the unauthorized use of bioresources by multinational corporations and other organizations without proper authorization from the countries and people involved. This practice is usually carried out without any compensatory payment to the communities whose resources are being used. Some nations are now creating laws to prevent such unauthorized exploitation of their bioresources and traditional knowledge.

In summary, **biopatents** are patents granted for biological entities and products derived from them, while **biopiracy** is the unauthorized use of bioresources by corporations and organizations without proper authorization and compensation to the affected communities.

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- **Biopiracy** : Use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned is biopiracy.
- **Biopatient** : Patents granted for biological entities and for products derived from them are called biopatients. e.g., Basmati Rice.

- Technique for correcting a defective gene through gene manipulation.
- First clinical gene therapy was given in 1990 to a 4-year old girl with adenosine deaminase (ADA) deficiency.

- Animals that have their DNA manipulated to possess or express an extra gene. e.g., Transgenic rats, rabbits, pigs, sheep, Rosie cow and fish.

- To study normal physiology and development.
- To study the contribution of genes in the development of a disease.
- Biological products.
- Vaccine safety testing.
- Chemical safety testing.

- Genetic Engineering Approval Committee
- Make decisions about the validity of GM research.
- Safety of GM-organisms for public services.

- Recombinant DNA technology
- Polymerase Chain Reaction.
- Enzyme Linked Immuno-sorbent Assay (ELISA).

Trace the Mind Map  
 ▶ First Level    ▶ Second Level    ▶ Third Level

- Stem cells are special human cells which are able to develop into many different cell types.
- The stem cell technology helps to grow new cells from stem cell in a laboratory to replace damaged organs or tissues.

Stem Cell Technology

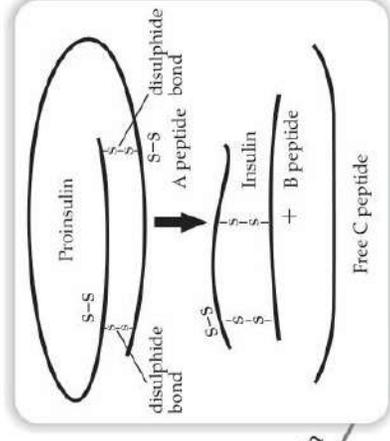
Advantages of GM Crops

- Makes crops more tolerant to abiotic stresses
- Reduces resilience on chemical pesticides.
- Helps to reduce post-harvest losses.
- Increases efficiency of mineral usage by plants.
- Enhances nutritional value of food. e.g., Golden rice.

- *Bacillus thuringiensis* contain Bt toxin, which is in inactive form.
- It becomes active toxin in the alkaline pH of insect gut.
- The activated toxin binds to the surface of midgut epithelial cells of insect and creates pores.
- This causes cell swelling and lysis and eventually death of the insect.
- The toxin is coded by a gene named cry. e.g., The proteins encoded by the genes *cryIAC* and *cryIIAb* control the cotton bollworms.

In Agriculture

Pest resistance in Cotton plant



- Antimerozoite vaccines
- Antigameteocyte vaccines
- Antisporozoite vaccines

In Medicine

Genetically Engineered insulin  
 Vaccine Production

BioTechnology and its Applications



Biopiracy and biopatient

Gene Therapy

Transgenic animals

Advantages

GEAC

Molecular diagnosis

Definition

## Practice Questions

1. Who developed the technique of DNA fingerprinting?

- a) Ian Wilmut      b) Har Gobind Khurana      c) Jacques Monod      d) Alec Jeffreys

2. Which of the following is an application of biotechnology?

- A) Producing biofuels      B) Designing computer hardware  
C) Developing new fashion trends      D) Constructing high-rise buildings

3. How can gene silencing be achieved?

- a) RNAi      b) Antisense RNA      c) Both (a) and (b)      d) None of these

4. What can induce roots in callus culture?

- a) Auxin      b) Cytokinin      c) Gibberellin      d) Ethylene

5. What is Golden Rice?

- a) I. A transgenic variety of rice  
b) II. Contains a good quality of beta-carotene (provitamin-A)  
c) III. Beta-carotene is a principal source of vitamin-A  
d) IV. The grains of the rice are yellow in color due to beta-carotene. The rice is commonly called Golden Rice

6. What does GEAC stand for?

- a) Genetic and Biotechnique Approval Committee      b) Gene Environment Action Committee  
c) Genetic Engineering Approval Committee      d) Genome Engineering Action Committee

7. What made it possible to link an antibiotic resistance gene with a plasmid vector?

- a) DNA ligase      b) Endonucleases      c) DNA polymerase      d) Exonucleases

8. How have genetically modified plants been useful?

- a) Crop yield
- b) Nutritional value of food
- c) Tolerance against abiotic stresses
- d) All of the above

9. Which of the following is a transgenic plant with natural resistance to insect pests?

- a) Tobacco and cotton
- b) Tomato and rice
- c) Maize and sugarcane
- d) Tomato and wheat

10. Which of the following options is commonly used in genetic engineering?

- a) Plastid
- b) Plasmid
- c) Mitochondria
- d) Endoplasmic reticulum

11. Which of the following terms best describes explants before organogenesis?

- a) Photosynthetic
- b) Autotrophic
- c) Heteromorphic
- d) Heterotrophic

12. What is used to silence genes in RNAi?

- a) Double-stranded DNA
- b) Double-stranded RNA
- c) Single-stranded DNA
- d) Single-stranded RNA

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13. Which restriction endonuclease recognizes the recognition site GAATTC?

- a) Eco RI
- b) Hind II
- c) Eco RII
- d) Bam HI

14. Consider the following statements about transgenic tobacco plants:

- I. They contain a gene from a bacterium.
- II. The gene is an insecticidal protein that damages the inner lining of insects and kills them.
- III. The tobacco plants produce their own insecticide.

Which of the statements above are correct?

- a) I and II                      b) I and III                      c) II and III                      d) I, II and III

15. What gene was introduced in the first transgenic cow?

- a) Human  $\alpha$ -lactalbumin                      b)  $\alpha$ -1-antitrypsin                      c) Casein                      d) cry-IAc

16. What bacteria was the first to be used as a biopesticide on a commercial scale in the world?

- a) *Bacillus thuringiensis*                      b) *E. coli*  
c) *Pseudomonas aeruginosa*                      d) *Agrobacterium tumefaciens*

17. What produces silk?

- a) Egg of silkworm                      b) Pupa of silkworm                      c) Larva of silkworm                      d) Insect itself

18. What is the most widely used bioweapon?

- a) *Bacillus subtilis*                      b) *Pseudomonas putida*  
c) *Bacillus anthracis*                      d) None of these

19. How does toxin kill insects?

- a) By inhibiting protein synthesis  
b) By generating excessive heat  
c) By creating pores in the midgut epithelial cells, leading to cell swelling and lysis  
d) By obstructing a biosynthetic pathway

20. What was GM brinjal in India developed for resistance against?

- a) Virus                      b) Bacteria                      c) Fungi                      d) Insects

21. Which of the following is the best genetic vector in plants?

- a) *Bacillus thuringiensis*                      b) *Agrobacterium tumefaciens*  
c) *Pseudomonas putida*                      d) None of the above

22. What is the purpose of genetic engineering in biotechnology?

- A) To create genetically modified organisms (GMOs)  
B) To study ancient civilizations  
C) To predict weather patterns  
D) To analyze geological formations

23. What is the function of polymerase chain reaction?

- a) Transduction                      b) DNA amplification                      c) Translation                      d) None of these

24. Gene amplification using primers can be achieved through which of the following techniques?

- a) Microinjection                      b) ELISA                      c) Polymerase chain reaction                      d) Gene gun

25. What is the name of the technique that involves the deliberate manipulation of genes within or between species?

- a) Gene therapy                      b) Hybridoma technology                      c) Tissue culture                      d) Genetic engineering

26. Why is it possible to produce a human protein in bacteria using genetic engineering?

- a) Bacterial cells can carry out RNA splicing reactions.  
b) The human chromosome can replicate in bacterial cells.  
c) The mechanism of gene regulation is identical in humans and bacteria.  
d) The genetic code is universal.

27. Which of the following statements is NOT true for a clone?

- a) Clones are descended from a single parent.
- b) Identical twins are not clones.
- c) A clone is the result of sexual reproduction.
- d) Both (a) and (c) are true.

28. Which company began selling Humulin in 1983?

- a) Baxter International
- b) Eli Lilly
- c) Roche
- d) Bayer Healthcare.

29. From which of the following organisms is Bt toxin obtained?

- a) Prokaryotes
- b) Eukaryotes
- c) Both prokaryotes and eukaryotes
- d) None of the above

30. Which transgenic human protein product has been used to treat emphysema?

- a) Alpha-1 antitrypsin
- b) Beta-globulin
- c) Cry I Ab protein
- d) Cry II Ac protein

31. What is biopiracy?

- a) The use of biological patents
- b) Theft of plants and animals
- c) The use of bioresources of a country without proper authorization
- d) Stealing of biological resources

32. Why is meristem culture practiced in horticulture?

- a) To obtain somaclonal variation
- b) To obtain haploids
- c) To obtain virus-free plants
- d) To obtain slow-growing callus

33. What is the term for the use of biology in industrial processes and for improving quality of life?

- a) Genetic engineering
- b) Eugenics
- c) Microbiology
- d) Biotechnology



40. What is a clone?

- a) An asexually produced heterozygote.
- b) An asexually produced homozygote.
- c) A heterozygote produced by sexual reproduction.
- d) A homozygote produced by sexual reproduction.

41. What is Humulin?

- a) Human insulin.
- b) Animal insulin.
- c) Bacterial insulin.
- d) Fungi insulin.

42. In Bt cotton, what does "Bt" refer to?

- a) Botanical.
- b) Beta.
- c) Biotechnology.
- d) Bacillus thuringiensis.

43. In 1990, M. Blease and W.F. Andresco of the National Institute of Health attempted gene therapy on a 4-year-old girl with which enzyme deficiency?

- A) Cytosine deaminase (CDA).
- b) Adenosine deaminase (ADA).
- c) Tyrosine oxidase.
- d) Glutamate trihydrogenase

44. Which is the most effective method for obtaining virus-free plants through tissue culture?

- a) Protoplast culture
- b) Embryo rescue
- c) Anther culture
- d) Meristem culture

45. Which genes were introduced into cotton to protect it from cotton bollworms?

- a) Cry Ac and cry Ab
- b) Bt Ac and Bt Ab
- c) Cry I Ac and cry II Ab
- d) Nif genes

46. Which techniques are related to gene therapy?

- I. Bone marrow transplantation
- II. Enzyme replacement therapy
- III. Gel electrophoresis technique
- IV. Hybridoma technique

Choose the correct option.

- a) I and II
- b) II and III
- c) I, II and III
- d) II, III and IV

47. 'Roise' cow known to produce a type of milk which has all the following characteristics

- I. Protein content of 2.4 g/L
- II. Human -lactalbumin
- III. More nutritionally balanced for human babies than natural cow milk

Which of the above statements are correct?

- a) I and II                      b) I and III                      c) II and III                      d) I, II and III

48. The SCID patient has a defective gene for the enzyme Adenosine Deaminase (ADA). He/She lacks functional \_\_\_\_ and therefore fails to fight the infecting pathogens.

- A) B-lymphocytes
- b) Phagocytes
- c) T-lymphocytes
- d) Both (a) and (b)

49. *Bacillus thuringiensis* is widely used in contemporary biology as a/an:

- a) Indicator of water pollution
- b) Insecticide
- c) Agent for production of dairy products
- d) Source of industrial enzyme

50. In plant biotechnology, PEG is used in:

- a) Protoplast isolation
- b) Cell culture preparation
- c) Protoplast fusion
- d) Hardening

## Answers

1. The correct answer is d) Alec Jeffreys. Alec Jeffreys developed the technique of DNA fingerprinting in 1984. This technique involves the analysis of DNA sequences to identify unique patterns that can be used to distinguish between individuals, such as in criminal investigations or paternity tests.

2. A) Producing biofuels

Explanation: Biotechnology involves the use of living organisms or their components to create useful products or solve problems. One important application of biotechnology is in the production of biofuels. Biofuels are renewable energy sources derived from biological materials such as crops, algae, or waste biomass. Biotechnology techniques can be used to enhance the production of biofuels by optimizing the growth and yield of biofuel crops, improving the efficiency of conversion processes, and developing new biofuel sources.

3. The correct answer is c) Both (a) and (b). Gene silencing can be achieved by introducing RNA molecules that are complementary to a specific mRNA molecule, either through the use of RNA interference (RNAi) or antisense RNA. These RNA molecules can bind to the target mRNA and prevent it from being translated into protein, effectively “silencing” the gene.

4. The correct answer is a) Auxin. Auxin is a plant hormone that is commonly used to induce root formation in callus cultures. Callus cultures are collections of undifferentiated plant cells that can be used for tissue culture and genetic engineering purposes.

5. The correct answer is d) IV. Golden Rice is a genetically modified variety of rice that has been engineered to produce beta-carotene, which is converted to vitamin A in the body. This rice is intended to provide a source of vitamin A to populations that may be deficient in this nutrient, particularly in developing countries where rice is a staple food.

6. The correct answer is c) Genetic Engineering Approval Committee. The Genetic Engineering Approval Committee (GEAC) is a regulatory body in India that is responsible for evaluating and approving genetically modified organisms (GMOs) for use in agriculture and food production.

7. The correct answer is b) Endonucleases. Endonucleases are enzymes that can cut DNA at specific sequences, and they have been used to insert antibiotic resistance genes into plasmid vectors. This allows researchers to select for cells that have taken up the plasmid vector by growing them on a medium containing the corresponding antibiotic.

8. The correct answer is d) All of the above. Genetically modified plants have been useful in a variety of ways, including increasing crop yields, improving the nutritional value of food, and increasing tolerance to abiotic stresses such as drought or high salinity.

9. The correct answer is a) Tobacco and cotton. Many transgenic plants have been developed with natural resistance to insect pests, often by introducing genes from other species that produce insecticidal proteins. Tobacco and cotton are two examples of transgenic plants with natural resistance to insect pests.

10. The correct answer is b) Plasmid. Plasmids are commonly used in genetic engineering as vectors for introducing new genes into cells. They are small, circular pieces of DNA that can replicate independently of the host cell's genome and can be easily manipulated in the laboratory.

11. d) Heterotrophic

Explanation: Explants are small pieces of plant tissue that are used for plant tissue culture. Before organogenesis, explants rely on external sources for their nutrient and energy needs, and therefore they are heterotrophic.

12. b) Double-stranded RNA

Explanation: RNAi (RNA interference) is a mechanism that can silence gene expression. Double-stranded RNA (dsRNA) is used to induce RNAi and can be artificially introduced into cells to target and degrade specific mRNA molecules, leading to the suppression of gene expression.

13. a) Eco RI

Explanation: Eco RI is a restriction endonuclease that recognizes the recognition site GAATTC and cleaves the DNA at this site.

14. d) I, II and III

Explanation: All three statements are correct. Transgenic tobacco plants have been genetically modified to contain a gene from the bacterium *Bacillus thuringiensis*, which encodes an insecticidal protein that damages the inner lining of insects and kills them. The plants produce their own insecticide and are resistant to insect damage.

15. a) Human -lactalbumin

Explanation: The first transgenic cow was created in 1982 and carried a human gene for -lactalbumin, a protein found in human milk.

16. a) *Bacillus thuringiensis*

Explanation: *Bacillus thuringiensis* (Bt) is a bacterium that produces proteins that are toxic to insects. Bt has been used as a biopesticide on a commercial scale since the 1950s.

17. c) Larva of silkworm

Explanation: Silk is produced by the larva of the domesticated silk moth, *Bombyx mori*.

18. c) *Bacillus anthracis*

Explanation: *Bacillus anthracis*, the causative agent of anthrax, is considered the most widely used bioweapon.

19. c) By creating pores in the midgut epithelial cells, leading to cell swelling and lysis

Explanation: Insects can be killed by toxins that create pores in their midgut epithelial cells, leading to cell swelling and lysis.

20. d) Insects

Explanation: GM (genetically modified) brinjal (eggplant) in India was developed for resistance against insects, particularly the fruit and shoot borer. The Bt gene was introduced into the brinjal to produce an insecticidal protein that protects against these pests.

21. b) *Agrobacterium tumefaciens*

Explanation: *Agrobacterium tumefaciens* is the most commonly used genetic vector for plant genetic engineering. It is a soil bacterium that naturally transfers a piece of its DNA (T-DNA) into the plant host's genome, causing the formation of tumors. This T-DNA can be replaced with a gene of interest to produce transgenic plants.

22.A) To create genetically modified organisms (GMOs)

Explanation: Genetic engineering is a technique used in biotechnology to manipulate an organism's DNA, allowing scientists to introduce specific genes into an organism or modify existing genes. The primary purpose of genetic engineering is to create genetically modified organisms (GMOs). GMOs are organisms whose genetic material has been altered in a way that does not occur naturally through mating or natural recombination. Genetic engineering enables scientists to enhance desired traits in organisms, such as improving crop yield, increasing resistance to pests or diseases, or producing valuable pharmaceuticals.

23.b) DNA amplification

Explanation: The polymerase chain reaction (PCR) is a laboratory technique used to amplify a specific segment of DNA. PCR uses a special enzyme called DNA polymerase to repeatedly copy and amplify a target DNA sequence in vitro.

24.c) Polymerase chain reaction

Explanation: Gene amplification using primers can be achieved through polymerase chain reaction (PCR). PCR uses short primers that are complementary to the sequences flanking the target DNA sequence. These primers are used to selectively amplify the target sequence.

25.d) Genetic engineering

Explanation: Genetic engineering is the deliberate manipulation of genes within or between species. This can involve the insertion, deletion, or modification of genes to produce desired traits.

26.d) The genetic code is universal.

Explanation: The genetic code is universal, meaning that the same sequence of nucleotides in DNA encodes the same amino acid in all living organisms. Therefore, it is possible to introduce a human gene into bacteria and have the bacteria produce the human protein by following the same genetic code.

27.c) A clone is the result of sexual reproduction.

Explanation: A clone is an individual that is genetically identical to its parent. Clones are usually produced asexually through processes such as mitosis or cloning by nuclear transfer. Sexual reproduction involves the fusion of gametes from two parents and results in offspring that are not genetically identical to either parent.

28.b) Eli Lilly

Explanation: Humulin is a brand of insulin used to treat diabetes. It was the first genetically engineered human pharmaceutical product to be approved by the US FDA for commercial use. It was developed by Genentech and marketed by Eli Lilly.

### 29.a) Prokaryotes

Explanation: Bt toxin is a protein produced by the bacterium *Bacillus thuringiensis* (Bt). It is toxic to certain insect pests and is used as a natural insecticide in organic farming and genetically modified crops.

### 30.a) Alpha-1 antitrypsin

Explanation: Alpha-1 antitrypsin is a protein that protects the lungs from damage caused by white blood cells. People with emphysema have low levels of this protein, which can lead to lung damage.

31. © Biopiracy refers to the use of bioresources of a country without proper authorization or compensation to the country of origin. It is essentially the theft of biological resources and traditional knowledge associated with these resources.

32.(c) Meristem culture is a technique used in horticulture to obtain virus-free plants. Meristem, the growing point of the plant, is excised and grown in culture, producing a virus-free plant that is genetically identical to the original plant.

33.(d) Biotechnology is the term used for the use of biology in industrial processes and for improving the quality of life. It includes the use of microorganisms, genetic engineering, and other techniques to develop products and processes for various industries.

34.(d) All three statements are correct. Protein crystals containing a toxic insecticidal protein, commonly known as Bt toxin, are produced by certain bacteria and are toxic to specific insect pests. The protein is activated by the alkaline pH of the gut of the insect pest and binds with the epithelial cells of the midgut of the insect pest, ultimately killing it. The carrier bacterium that carries the protein is itself resistant to the toxin and is not killed by it.

35.(a) Gene therapy is the term used for the treatment of a genetic disorder by manipulating genes. This may involve inserting a normal gene into a patient's cells to replace a defective one, repairing or modifying a defective gene, or regulating the expression of a gene.

36.(a) The three distinct steps in PCR (polymerase chain reaction) occur in the following order: denaturation, annealing, and synthesis. During denaturation, the double-stranded DNA template is heated to separate the two strands. During annealing, short DNA primers bind to the template strands. During synthesis, the polymerase enzyme extends the primers and synthesizes new strands of DNA.

37.(a) Lymphocytes are a type of white blood cell that plays a key role in the immune system. They are responsible for identifying and attacking foreign substances, such as bacteria and viruses, and also play a role in the development of immunity to future infections.

38.(a) Golden rice is a genetically modified rice variety that is rich in beta-carotene, which is converted to vitamin A in the body. Vitamin A deficiency is a major cause of blindness in poor countries, and golden rice can be used to prevent this deficiency and subsequent blindness.

39.(a) The Bt toxin is not toxic to human beings because it specifically targets insects. The toxin binds to receptors in the gut of susceptible insect pests, which have a specific structure that is absent in human beings. Therefore, the toxin does not affect human beings or other non-target organisms.

40. Answer: b) An asexually produced homozygote.

Explanation: A clone is a group of genetically identical organisms, which are produced asexually (without the involvement of gametes) from a single parent. A clone may be homozygous or heterozygous, but the most common usage of the term refers to a homozygote.

41. Answer: a) Human insulin.

Explanation: Humulin is a brand name for human insulin, which is a synthetic form of insulin that is used to treat diabetes. Human insulin is produced using recombinant DNA technology, in which the human insulin gene is inserted into bacterial or yeast cells, which then produce the insulin.

42. Answer: d) *Bacillus thuringiensis*.

Explanation: Bt cotton is a genetically modified variety of cotton that contains a gene from the bacterium *Bacillus thuringiensis*, which produces a protein toxic to certain insects that feed on cotton plants. The Bt gene allows the cotton plants to produce the Bt toxin, which protects the plants from pests such as the cotton bollworm.

43. Answer: b) Adenosine deaminase (ADA).

Explanation: Adenosine deaminase (ADA) is an enzyme that is essential for the normal functioning of the immune system. Deficiency of this enzyme results in severe combined immunodeficiency (SCID), a rare genetic disorder that leaves affected individuals highly susceptible to infections. In 1990, M. Blaese and W.F. Anderson of the National Institute of Health attempted gene therapy on a 4-year-old girl with ADA deficiency, using genetically modified cells to replace the defective gene.

44. Answer: d) Meristem culture

Explanation: Meristem culture is a tissue culture technique that involves the growth of plants from the meristematic tissue, which is the region of the plant that contains the actively dividing cells. This technique is highly effective for obtaining virus-free plants, as the meristem tissue is usually free of viral infection. In contrast, other tissue culture techniques such as anther culture or protoplast culture may carry over viral infections from the original plant.

45. Answer: a) Cry Ac and cry Ab

Explanation: Cry Ac and Cry Ab are two genes from the bacterium *Bacillus thuringiensis* that produce proteins toxic to certain insects, including the cotton bollworm. These genes were introduced into cotton plants through genetic engineering to produce Bt cotton, which is resistant to the cotton bollworm and other pests.

46. Answer: (a) I and II

Explanation:

- I. Bone marrow transplantation involves the transfer of bone marrow stem cells from a healthy donor to a patient with a genetic disorder that affects the bone marrow cells. This technique is used in gene therapy to replace the defective or missing genes responsible for the disorder.
- II. Enzyme replacement therapy is used to treat genetic disorders caused by missing or defective enzymes. The therapy involves injecting functional enzymes into the patient's bloodstream to replace the missing or defective ones. Gene therapy can be used to deliver the functional genes to the patient's cells to produce the missing or defective enzymes.

47.. Answer: (d) I, II and III

Explanation:

- I. Roise cow's milk has a protein content of 2.4 g/L, which is a correct statement.
- II. Roise cow's milk contains human-lactalbumin, which is a correct statement.
- III. Roise cow's milk is more nutritionally balanced for human babies than natural cow milk, which is a correct statement.

Therefore, all three statements are correct, and the correct answer is option (d).

48. Answer: © T-lymphocytes

Explanation:

The enzyme Adenosine Deaminase (ADA) is required for the normal development and function of T-lymphocytes, which play a crucial role in the immune system's defense against infections. In SCID (Severe Combined Immunodeficiency), a genetic disorder, the gene for ADA is defective, leading to the absence or deficiency of ADA enzyme. As a result, the development and function of T-lymphocytes are impaired, leading to an increased susceptibility to infections.

Therefore, the correct answer is option © T-lymphocytes.

49. Answer: (b) Insecticide

Explanation:

*Bacillus thuringiensis* (Bt) is a soil bacterium that produces insecticidal proteins called Bt toxins. These toxins specifically target and kill certain insect pests while being safe for humans, animals, and beneficial insects. Bt is widely used in contemporary biology as an insecticide to control agricultural pests, mosquito-borne diseases, and forest pests.

Therefore, the correct answer is option (b) Insecticide.

50. Answer: © Protoplast fusion

Explanation:

Polyethylene glycol (PEG) is used in plant biotechnology to promote the fusion of protoplasts, which are plant cells that have had their cell walls removed. Protoplast fusion is a technique used to produce somatic hybrids by fusing two different plant protoplasts. The technique is useful in plant breeding, genetic engineering, and plant tissue culture.

Therefore, the correct answer is option © Protoplast fusion.