Biotechnology and Its Applications

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CLASS: XII **BIOLOGY**

Very Short Answer Type Questions

1. What is Biotechnology?

Biotechnology is the branch of biology deals with industrial scale production of biopharmaceuticals and biologicals using genetically modified microbes, fungi, plants and animals.

2. Name the areas of applications of biotechnology.

The applications of biotechnology include therapeutics, diagnostics, and genetically modified crops for agriculture, processed food, bioremediation, waste treatment, and energy production.

3. What is gene therapy?

Gene therapy is a collection of methods that allows correction of a gene defect that has been diagnosed in a child/embryo.

4. How many varieties of rice are there in India?

There are an estimated 200,000 varieties of rice in India alone.

5. What are Genetically Modified Organisms?

Plants, bacteria, fungi and animals whose genes have been altered by manipulation are called Genetically Modified Organisms (GMO).

4. What could decrease the amount of pesticide used?

Pest resistant plants could decrease the amount of pesticide used.

6. What are the different forms of CRY genes? What do they control?

There are a number of them, for example, the proteins encoded by the genes cryIAc and cryIIAb control the cotton bollworms that of cryIAb controls corn borer.

7. How can we minimise the use of fertilisers and chemicals so that their harmful effects on the environment are reduced?

We can minimise the use of fertilisers and chemicals so that their harmful effects on the environment are reduced by the use of genetically modified crops.

8. How many recombinant therapeutics have been approved for human-use the world over and in India?

At present, about 30, recombinant therapeutics have been approved for human-use the world over. In India, 12 of these are presently being marketed.

Short Answer Type Questions

1. What is Biopiracy?

Biopiracy is the use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned without compensatory payment

2. Name the latest techniques that serve the purpose of early diagnosis.

Recombinant DNA technology, Polymerase Chain Reaction (PCR) and Enzyme Linked Immuno Sorbent Assay (ELISA) are some of the techniques that serve the purpose of early diagnosis.

3. Why does Bt toxin not kill the Bacillus?

The Bt toxin protein exists as inactive protoxins but once an insect ingests the inactive toxin, it is converted into an active form of toxin due to the alkaline pH of the gut which solubilize the crystals.

The activated toxin binds to the surface of midgut epithelial cells and creates pores that cause cell swelling and lysis and eventually cause death of the insect.

4. What are the advantages of biotechnological applications in medicine?

The recombinant DNA technological processes have made immense impact in the area of healthcare by enabling mass production of safe and more effective therapeutic drugs.

Further, the recombinant therapeutics does not induce unwanted immunological responses as is common in case of similar products isolated from non-human sources.

5. What are the three critical research areas of biotechnology?

(i) Providing the best catalyst in the form of improved organism usually a microbe or pure enzyme.

(ii) Creating optimal conditions through engineering for a catalyst to act.

(iii) Downstream processing technologies to purify the protein/organic compound.

6. What are three options that can help in increasing food production?

(i) Agro-chemical based agriculture.

(ii) Organic agriculture.

(iii) Genetically engineered crop-based agriculture.

7. Name the latest techniques that serve the purpose of early diagnosis. How is early diagnosis done?

Recombinant DNA technology, Polymerase Chain Reaction (PCR) and Enzyme Linked Immuno Sorbent Assay (ELISA) are some of the techniques that serve the purpose of early diagnosis.

Presence of a pathogen (bacteria, viruses, etc.) is normally suspected only when the pathogen has produced a disease symptom.

By this time the concentration of pathogen is already very high in the body.

However, very low concentration of a bacteria or virus (at a time when the symptoms of the disease are not yet visible) can be detected by amplification of their nucleic acid by PCR.

Short Answer Type Questions

1. Can you explain how PCR can detect very low amounts of DNA? PCR is now routinely used to detect HIV in suspected AIDS patients.

It is being used to detect mutations in genes in suspected cancer patients too.

It is a powerful technique to identify many other genetic disorders

A single stranded DNA or RNA. tagged with a radioactive moecu1e (probe) is allowed to hybridize to its complementary DNA in a clone of cells followed by detection using autoradiography.

The clone having the mutated gene will hence not appear on the photographic film, because the probe will not have complementarity with the mutated gene

ELISA is based on the principle of antigen-antibody interaction.

Infection by pathogen can be detected by the presence of antigens (proteins, glycoproteins, etc.) or by detecting the antibodies synthesised against the pathogen.

2. (a) When was the first clinical gene therapy done?

(b) What was the disorder?

(c) How is it caused?

(d) How can it be cured?

OR

If a person is born with a hereditary disease, can a corrective therapy be taken for such a disease? How is it done?

(a) The first clinical gene therapy was given in 1990 to a 4-year old girl.

(b) The disorder was adenosine deaminase (ADA) deficiency. This enzyme is crucial for the immune system to function.

Cause of ADA deficiency:

The disorder is caused due to the deletion of the gene for adenosine deaminase.

Cure:

ADA deficiency can be cured by the following ways.

1. Bone marrow transplantation:

In some children ADA deficiency can be cured by bone marrow transplantation;

2. Enzyme Replacement Therapy:

In others it can be treated by enzyme replacement therapy, in which functional ADA is given to the patient by injection.

3. Gene Therapy:

As a first step towards gene therapy, lymphocytes from the blood of the patient are grown in a culture outside the body.

A functional ADA cDNA (using a retroviral vector) is then introduced into these lymphocytes, which are subsequently returned to the patient.

However, as these cells are mortal, the patient requires periodic infusion of such genetically engineered lymphocytes.

If the gene isolate from marrow cells producing ADA is introduced into cells at early embryonic stages. It could be a permanent cure.

3. What are the advantages of Genetic modification?

(i) Made crops more tolerant to biotic stresses (cold, drought, salt, heat).

(ii) Reduced reliance on chemical pesticides (pest-resistant crops).

(iii) Helped to reduce post-harvest losses.

(iv) Increased efficiency of mineral usage by plants (this prevents early exhaustion of fertility of soil).

(v) Enhanced nutritional value of food, e.g., Vitamin A enriched rice

In addition to these uses, GM has been used to create tailor-made plants to supply alternative resources to industries, in the form of starches, fuels and pharmaceuticals.

4. (a) How is Bt toxin produced?

(b) What are the plants in which the gene for Bt-Toxin is introduced?

(c) Name the insects that are killed by Bt-Toxin.

(a) Bt-toxin is produced by a bacterium called Bacillus thuringiensis (Bt for short).

Bt-toxin gene has been cloned from the bacteria and been expressed in plants to provide resistance to insects without the need for insecticides; in effect created a bio-pesticide.

(b) The plants in which the gene for Bt Toxin is introduced are Bt cotton, Bt corn, rice, tomato, potato and soya bean etc.

(c) The insects that are killed by Bt-toxin are some strains of Bacillus thuringiensis produce proteins that kill certain insects such as lepidopterans (tobacco budworm, armyworm), coleopterans (beetles) and dipterans (flies, mosquitoes).

B. thuringiensis forms protein crystals during a particular phase of their growth. These crystals contain a toxic insecticidal protein.

5. Name a nematode that infects the roots of tobacco plants and causes a great reduction in yield. Describe the strategy adopted to prevent this infestation.

Meloidegyne incognita is the nematode that infects the roots of tobacco plants and causes a great reduction in yield.

Strategy:

A novel strategy was adopted to prevent this infestation which was based on the process of RNA interference (RNAi).

RNAI takes place in all eukaryotic organisms as a method of cellular defense.

This method involves silencing of a specific mRNA due to a complementary dsRNA molecule that binds to and prevents translation of the mRNA (silencing).

Source of Complementary RNA:

The source of this complementary RNA could be from an infection by viruses having RNA genomes or mobile genetic elements (transposons) that replicate via an RNA intermediate.

Vector Used:

Using Agrobacterium vectors, nematode-specific genes were introduced into the host plant

The introduction of DNA was such that it produced both sense and anti-sense RNA in the host cells.

These two RNAs being complementary to each other formed a double stranded (dsRNA) that initiated RNAI and thus, silenced the specific mRNA of the nematode.

Consequence:

The consequence was that the parasite could not survive in a transgenic host expressing specific interfering RNA.

The transgenic plant therefore got itself protected from the parasite

6. What is Biopiracy? Describe the factors that lead to biopiracy. Why do some nations develop laws to prevent such unauthorized exploitation of their bio-resources and traditional knowledge?

Biopiracy:

Biopiracy is the use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned without compensatory payment.

Factors that lead to biopiracy

Most of the industrialized nations are rich financially but poor in biodiversity and traditional knowledge.

In contrast the developing and the underdeveloped world is rich in biodiversity and traditional knowledge related to bio-resources.

Traditional knowledge related to bio-resources can be exploited to develop modern applications and can also be used to save time, effort and expenditure during their commercialization.

Laws to prevent unauthorized exploitation of their bio-resources and traditional knowledge:

There has been growing realization of the injustice, inadequate compensation and benefit sharing between developed and developing countries.

Therefore, some nations are developing laws to prevent such unauthorized exploitation of their bio-resources and traditional knowledge.

The Indian Parliament has recently cleared the second amendment of the Indian Patents Bill that takes such issues into consideration, including patent terms, emergency provisions and research and development initiative.

Long Answer Type Questions

1. Would the insulin isolated from other animals be just as effective as that secreted by the human body itself and would it not elicit an immune response in the human body?

Insulin used for diabetes was earlier extracted from pancreas of slaughtered cattle and pigs.

Insulin from an animal source though caused some patients to develop allergy or other types of reactions to the foreign protein.

Structure of Insulin:

Insulin consists of two short polypeptide chains: chain A and chain B, that are linked together by disulphide bridges

In mammals, including humans, insulin is synthesized as a pro- hormone.

The pro-hormone needs to be processed before it becomes a fully mature and functional hormone that contains an extra stretch called the C peptide.

This C peptide is not present in the mature insulin and is removed during maturation into insulin.

The main challenge for production of insulin using rDNA techniques was getting insulin assembled into a mature form.

Synthesis of Insulin:

In 1983, Eli Lilly an American company prepared two 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 disulfide bonds to form human insulin.

If bacteria were available that could make human insulin, suddenly the whole process becomes so simple.

We can easily grow a large quantity of the bacteria and make as much insulin as you need.

2. What are transgenic animals? Why are these animals being produced? How can man be benefitted from such modifications?

The animals which possess a foreign gene are called Transgenic animals.

Transgenic rats, rabbits, pigs, sheep, cows and fish have been produced, although over 95 per cent of all existing transgenic animals are mice.

1. Normal Physiology and Development:

Transgenic animals can be specifically designed to allow the study of gene regulation and how they affect the normal functions of the body and its development, e.g., study of complex factors involved in growth such as insulin-like growth factor.

The biological role of the genes can be studied in the body by introducing genes from other species that alter the formation of this gene.

2. Study of Disease:

They increase our understanding about the contribution of genes to the development of disease.

They serve as models for human diseases so that investigation of new treatments for diseases is made possible.

Transgenic models exist for many human diseases such as cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer

3. Biological Products:

Medicines required to treat certain human diseases can contain biological products, but such products are often expensive to make.

Biological products such as human protein (a- 1 -antitrypsin) used to treat emphysema can be created by the introduction of the portion of a DNA into the transgenic animals.

Similar attempts are being made for treatment of phenylketonuria (PKU) and cystic fibrosis.

In 1997, the first transgenic cow, Rosie, produced human protein-enriched milk (alpha-lactalbumin 2.4 grams per litre). It was nutritionally a more balanced product for human babies than natural cow-milk.

4. Vaccine Safety:

Transgenic mice are being developed for testing the safety of vaccines before they are used on humans.

Transgenic mice are being used to test the safety of the polio vaccine.

If successful and found to be reliable, they could replace the use of monkeys to test the safety of batches of the vaccine.

5. Chemical Safety Testing:

This is known as toxicity/safety testing.

As the transgenic animals carry genes, they are more sensitive to toxic substances than non-transgenic animals.

They are exposed to the toxic substances and the effects are studied.

Toxicity testing in such animals will allow us to obtain results in less time.

3. Describe the ethical issues of genetic modification of organisms or transgenic animals. What is the role of GEAC?

Unpredictable Results:

Genetic modification of organisms can have unpredictable results when such organisms are introduced into the ecosystem.

Patent Problem:

The modification/usage of living organisms for public services (as food and medicine sources, for example) has also created problems with patents granted for the same.

There is growing public anger that certain companies are being granted patents for products and technologies that make use of the genetic materials, plants and other biological resources that have long been identified, developed and used by farmers and indigenous people of a specific region/country.

Role of GEAC:

Therefore, the Indian Government has set up organisations such as GEAC (Genetic Engineering Approval Committee), which will make decisions regarding the validity of GM research and the safety of introducing GM-organisms for public services.

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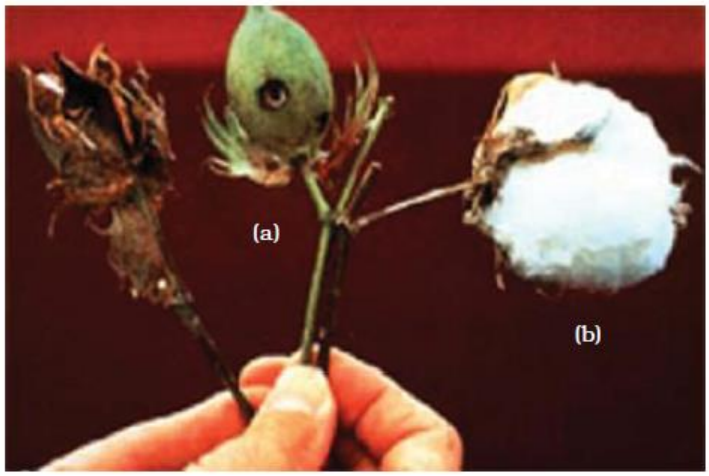
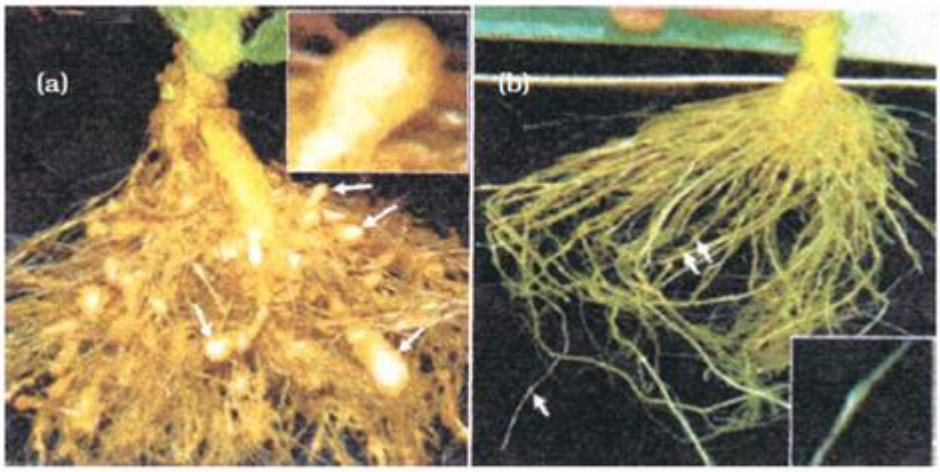
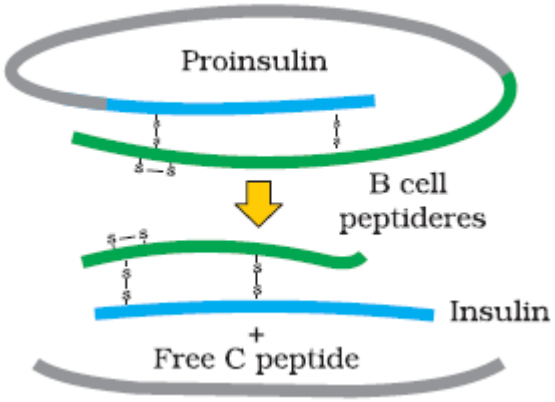


Cotton boll
(a) destroyed by bollworms
(b) a fully mature cotton boll



Host plant-generated dsRNA triggers protection against nematode infestation.
(a) Roots of a typical control plant.
(b) Transgenic plant roots 5 days after deliberate infection of nematode but protected through novel mechanism.



Maturation of
pro-insulin into insulin
after removal of C-peptide