**Definitions:**

**DNA**: Acronym for deoxyribonucleic acid, which is a molecule that contains an organism's complete genetic information.

**nucleotide**: The building block of DNA.

**gene**: The molecular unit of an organism that contains information for a specific trait (specific DNA sequence).

**genome**: An entire set of genes for an organism.

**plasmid**: The circular DNA structure used by bacteria.

**protein**: Large biomolecules used by an organism for a number of purposes; in this context, to express a desired trait.

**trait**: A distinguishing characteristic.

**recombinant DNA**: DNA to which a section has been removed and replaced (recombined) with a new sequence.

**Restriction enzyme**: An enzyme that "cuts" DNA when specific base pair sequences are present.

**GMO**: Acronym for genetically modified organism.

**Intrduction:**

**Genetic engineering, recombinant DNA technology and biotechnology** arebuzz words you may have heard often on radio or TV, or read about in featured articles in newspapers or popular magazines. The term genetic engineering was coined in 1919 by Karl Ereky, a Hungarian engineer. At that time, the term included all the processes by which products are obtained from raw materials with the aid of living organisms.

Nowadays, genetic engineering is defined as any technological application (a set of techniques) that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.

Genetic engineering is the direct modification of an organism’s genome, which is the list of specific traits (genes) stored in the DNA. Changing the genome enables engineers to give desirable properties to different organisms. Organisms created by genetic engineering are called genetically modified organisms (GMOs).

**Historical events associated with genetic engineering:**

Providing bread with leaven Prehistoric period

Fermentation of juices to alcoholic beverages Prehistoric period

Knowledge of vinegar formation from fermented juices Prehistoric period

Manufacture of beer in Babylonia and Egypt 3rd century BC

Wine manufacturing in the Roman Empire 3rd century AD

Production of spirits of wine (ethanol) 150

Vinegar manufacturing industry 14th century AD

Discovery of the fermentation properties of yeast 1818

Description of the lactic acid fermentation by Pasteur 1857

Detection of fermentation enzymes in yeast by Buchner 1897

Discovery of penicillin by Fleming 1928

Discovery of many other antibiotics ≈1945

An overview of important events in the development of modern molecular biology and recombinant DNA technology is provided in Table below:

Double helix structure of DNA is first described by Watson and Crick 1953

Cohen and Boyer, amongst others, develop genetic engineering 1973

The first human protein (somatostatin) is produced in a bacterium *(E. coli)* 1977

The first recombinant protein (human insulin) approved for the market 1982

Polymerase chain reaction (PCR) technique developed 1983

Launch of the Human Genome Project 1990

Began to sell genetically modified food 1994

Began to sell GMOs as pets (Glofish) 2003

The first genome sequence of an organism *(Haemophilus influenzae)* is determined 1995

A first draft of the human genome sequence is completed 2000

Over 40 million gene sequences are deposited in GenBank, and genome sequences of hundreds of prokaryotes and dozens of eukaryotes are finished or in draft stage 2005

About three decades ago, with the advance of molecular biology, genetic engineering became more of a science than an art. Regions of deoxyribonucleic acid (DNA) (called genes) were found to contain information that directs the synthesis of specific proteins. Proteins can therefore be considered as the final product of a Gene; they are the molecules that carry out almost all essential processes within a cell. Each protein has its own identity and function: many are so-called enzymes that catalyse (facilitate) chemical reactions, others are structural components of cells and organs. Today it is possible to express a gene, regardless of its origin, in a simple bacterium such as *Escherichia coli* (*E. coli*), so that the bacterium produces large quantities of the protein coded for by the gene. The same principle can be applied to many other micro-organisms, as well as to higher organisms such as plants and animals.

The techniques used for this purpose include:

**»** isolation of the gene coding for a protein of interest;

**»** cloning (i.e. transfer) of this gene into an appropriate production host;

**»** improving gene and protein expression by using stronger promoters, improving fermentation conditions etc. Together, these techniques are known as **Genetic** **engineering** (**recombinant DNA technology)**

**Applications of genetic engineering**

Since the advance of recombinant DNA technology, several techniques and applications have been developed that are benefiting humankind in the areas of agriculture, medicine, environment, industry and forensics. The following sections briefly describe some of these applications and their potential benefits to society.

1. **Industry**

Genetic engineering can be used to develop alternative fuels; an example is the conversion of maize starch into ethanol by yeast, which is subsequently used to produce gasohol (a gasoline-ethanol mix). Bacteria are used to decompose sludge and landfill wastes. Through genetic engineering, micro-organisms or their enzymes can be adapted to convert biomass into feed stocks, or they can be used for manufacturing biodegradable plastics (bioplastics). Other organisms (micro-organisms, plants and mammals) are used as bioreactors for producing chemical compounds that are extracted from them and processed as drugs and other products. Plant and animal fibers are used for producing a variety of fabrics, threads and cordage. Genetic engineering is applied to improve the quality and quantity of these products. Biopulping is a technique whereby a fungus is used to convert wood chips into pulp for papermaking.

2. **Health and medicine**

In the area of health and medicine, genetic engineering has numerous and important functions. Genetic engineering is used to develop diagnostic tools for identifying diseases.

Genetic engineering is also used to produce more effective and efficient vaccines, therapeutic antibodies, antibiotics, and other pharmaceuticals. Genetic engineering is a USD 70 billion a year industry that has produced several blockbuster drugs and vaccines, i.e. drugs with sales volumes exceeding USD 1 billion per year. Furthermore, there are more than 370 drug products and vaccines obtained through biotechnology currently in clinical trials, targeting more than 200 diseases including various cancers, Alzheimer’s disease, heart disease, diabetes, multiple sclerosis, AIDS and arthritis.

Through the genetic engineering of gene therapy, scientists are making efforts at

curing genetic diseases by attempting to replace defective genes with the correct version. A revolutionary strategy is being developed whereby staple foods such as potatoes, bananas, and others are used as delivery vehicles to facilitate the immunization of people in economically depressed regions of the world.

3. **Environment**

Development and usage of alternative fuels that burn cleaner and improve air quality through reduced pollution of the environment is possible by genetic engineering means. Micro-organisms are used to decompose wastes and clean up contaminated sites by the technology of bioremediation. The use of disease-resistant cultivars can make crop production less environmentally intrusive by reducing the use of agrochemicals.

4. **Forensics**

Since the DNA profile, i.e. the nucleotide sequence of the genome, is unique in

every individual, it can be used as a powerful basis of identifying individuals in a population. DNA-based evidence is used in cases involving paternity disputes and family relationships. Furthermore, it is used in health care and judicial systems. In the judicial system, forensic experts use DNA profiling to identify suspects in criminal cases, especially when body fluids and other particles like hair and skin samples can be retrieved.

5. **Agriculture**

Biotechnology can complement conventional breeding for crop and animal improvement. Instead of extensive re-arrangement of genes, as occurs in conventional breeding, biotechnology enables targeted gene transfer to occur. The genome of the recipient individual remains intact, except for the introduced gene (or genes), thus accelerating breeding programs and the development of organisms with desirable characteristics. Furthermore, biotechnology enables gene transfer across natural breeding boundaries, overcoming mating barriers and creating a “universal gene pool” or “universal breeding population” accessible to all organisms. Likewise, it is possible to specifically introduce novel, desirable traits and characteristics into existing species. This biotechnological application is used to improve the yield of crop and animal species and their product quality such as nutritional value and shelf life. In addition to these benefits, this methodology reduces the need for agrochemicals by creating disease and pest-resistant species, thereby reducing environmental pollution from chemical runoff. Increased yields and higher food quality can contribute to reducing world hunger and malnutrition.

Several technologies in the field of **agricultural biotechnology** exist that do not rely on the creation of GMO s. Molecular techniques are being used to monitor breeding populations and to diagnose animals and plants infected with diseases. Micropropagation techniques are being widely used to generate clonal plant materials, allowing rapid large-scale clonal propagation of many plant species including trees. Biofertilizers and biopesticides can be applied in place of conventional fertilizer and pesticides to promote plant growth and health in an environmentally sustainable way.

**Environmental risks of genetic engineering**

Before release into commerce, genetically engineered organisms are first assessed for possible risks, including risks to the environment. The present paper first identifies the environmental risks recognized by regulators, and reviews the parameters considered predictive of risk. Recent field-scale studies suggest opportunities for improvement of the environmental risk assessment process. Risks unique to genetically engineered crops – if any – could pertain to the specific traits chosen for commercialization and to unintended trait expression caused by the process of transgene insertion itself. Both the standard against which to compare genetically engineered traits and the scale of exposure need to be considered when assessing environmental impact. Evidence of environmental risk in the recognized areas on agricultural land, invasiveness of unmanaged systems, and non-target impacts from *Bacillus* thuringiensis (Bt) maize is presented. Targeted, statistically sound, rigorously conducted, multi-trophic studies analogous to the Field Scale Evaluation trials recently completed in the UK are needed to clarify the many questions which remain unanswered.

**What is the GMO process?**

All genetic changes affect the protein synthesis of the organism. By changing which proteins are produced, genetic engineers can affect the overall traits of the organism.

Most recombinant DNA technology involves the insertion of foreign genes into the plasmids of common laboratory strains of bacteria. Plasmids are small rings of DNA; they are not part of the bacterium’s chromosome (the main repository of the organism’s genetic information). Nonetheless, they are capable of directing protein synthesis, and, like chromosomal DNA, they are reproduced and passed on to the bacterium’s progeny. Thus, by incorporating foreign DNA (for example, a mammalian gene) into a bacterium, researchers can obtain an almost limitless number of copies of the inserted gene. Furthermore, if the inserted gene is operative (i.e., if it directs protein synthesis), the modified bacterium will produce the protein specified by the foreign DNA.

Genetic modification can be completed by a number of different methods:

1-Inserting new genetic material randomly or in targeted locations

2-Direct replacement of genes (recombination)

3-Removal of genes

4-Mutation of existing genes

**Question in genetic engineering:**

**Q1)** Which of the following would be considered recombinant DNA?

* The human insulin gene
* A bacterial transcription gene combined with a human promoter
* A viral genome
* A bacterial plasmid
* A pure bred dog through three generations, such as a golden retriever

**Q2)** A scientist isolates a human DNA repair gene and inserts it into a plasmid. The plasmid is inserted into a bacterial cell, so more plasmid can be produced. After isolating the plasmid from the bacterial cells, the scientist inserts the plasmid DNA into a human tissue culture cell using a virus. Which of the following statements is true?

* This experiment did not involve the use of vectors.
* One vector was used in this experiment.
* Two different vectors were used in this experiment.
* Three different vectors were used in this experiment.
* Four different vectors were used in this experiment.

**Q3)** A scientist isolates a human DNA repair gene and inserts it into a plasmid. The plasmid is inserted into a bacterial cell, so more plasmid can be produced. After isolating the plasmid from the bacterial cells, the scientist inserts the plasmid DNA into a human tissue culture cell using a virus. Which of the following statements is true?

* This experiment did not involve the use of hosts.
* One host was used in this experiment.
* Two different hosts were used in this experiment.
* Three different hosts were used in this experiment.
* Four different hosts were used in this experiment.

**Discussion:**

What part of an organism contains all of the information needed for it to function? When genes are expressed, what is the final product made?

Does anyone know why bacteria are modified more than other organisms?

What are some ethical and moral concerns that genetic engineers must consider? Does anyone think it is a good idea to genetically modify people?

Some researchers say this could be an approach to cure diseases such as Down's syndrome and other genetic defects. Superficial changes could also be made, such as determining a person's height, eye color or gender, by making changes to embryos in the mothers' wombs. But just because something can be done, does that make it a good idea?

Could Spiderman be real?



