



FAQ on Genetic Engineering

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From Human, Monkey & >12

1. What is a GMO?

A GMO is short for genetically modified organism, also known as genetically engineered organism, or transgenic organism. It carries genetic material that has been made in the laboratory and transferred into it by genetic engineering.

2. What is the genetic material, and where is it found?

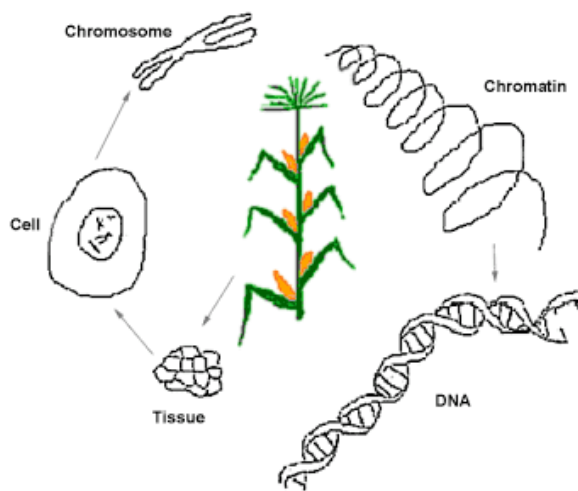


Figure 1. From plant to DNA

The genetic material is DNA (deoxyribonucleic acid). It is usually found in every cell, from microorganisms that have only one cell, to plants and animals that have many cells, where the cells make up tissues and organs. The cell and its constituents can be seen only with the help of increasingly powerful microscopes (see Fig. 1).

Inside a cell from a plant or animal, the genetic material is enclosed in a spherical compartment, the nucleus. It is packaged into long compact structures called chromosomes. The totality of all the genetic material packaged into chromosomes is the genome. Each species has a different genome. For example, there are 23 pairs of chromosomes

in the human genome, one of each pair from each parent. Bacteria have chromosomes which are not enclosed in a nucleus. The *E.coli* bacterium, which lives in the gut of mammals and human beings, has only one chromosome in its genome.

Each chromosome is really a very long molecule of DNA wound up and coiled around special proteins to form chromatin. (In animals and plants, each chromosome is duplicated but remains joined up at one point.) The DNA molecule itself, when stripped of all the bound proteins, consists of two strands wound around each other in a double helix. Each thread is made up of a long string of units joined end to end. There are four different units in DNA, labelled with the letters A, T, G, and C, which standing for the identifying bases for each unit, adenine, thymine, guanine and cytosine.

The bases of the two DNA strands pair up, A in one strand with T on the other, and G with C. The bases stick out at right angles from the backbone of each strand, with the result that the double helix looks like a spiral ladder, with the paired bases forming the rungs of the ladder. On account of the specific base-pairing, the sequence of the bases on one strand is complementary to that on the other. In other words, each strand is a template for making the other strand, and this provides the basis for exact replication, which is one of the functions of the genetic material.

DNA is the genetic material in all organisms. Many viruses - genetic parasites that depend on the cell to multiply copies of themselves - make use of RNA as genetic material. RNA is similar to DNA except that in place of the base thymine (T), it has uracil (U), and it usually does not exist in double-stranded forms. RNA is also involved in transcribing the base sequence of DNA in the first step of protein synthesis (see later).

3. What does the genetic material do?

The genetic material is replicated and passed on from one generation to the next in reproduction, and accounts for some of the resemblance between parents and offspring, although the way the genetic material works is highly complex and strongly dependent on the environment.

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One of the earliest discoveries on what DNA does, besides providing for its own replication, is that certain stretches, called *genes*, specifies the structure of proteins that are made, through a 'genetic code'. Three successive bases, a 'triplet', codes for one of twenty different amino acids that are strung together to make proteins. There are 4^3 ($4 \times 4 \times 4$) or 64 possible triplets from 4 bases, so more than one triplet often codes for one amino acid, and there are triplets for 'start' and 'stop'.

Proteins perform all the vital functions in the body, and the amino acid sequence of each protein and its folded three-dimensional structure are especially suited to carry out a specific function. Other stretches of the DNA enable the proteins to interact with one another and with the environment, to regulate when, where, by how much and for how long each gene is expressed, ie, when the protein specified by the gene is made in the cell.

It is a mistake to think, as most biologists did at least up to the mid-1970s, that there is a one-way flow of 'genetic information', from DNA to protein. Feed-back from the environment is crucial, and results in a lot of chopping and changing in between genes and proteins, often altering the DNA itself (see *Genetic Engineering Dream or Nightmare?* by Mae-Wan Ho, order information on ISIS website, especially the Chapter on 'The Fluid and Adaptable Genome')

4. What is genetic engineering?

Genetic engineering is a set of laboratory techniques for isolating genetic material from organisms, cutting and rejoining it to make new combinations, multiplying copies of the recombined genetic material (also called recombinant DNA) and transferring it into organisms, bypassing the process of reproduction. Genes can be exchanged between species that would never interbreed in nature. Thus, spider genes end up in the goat, human genes in plants, mice, and bacteria, and bacterial genes in plants.

5. How is a GMO made?

To make a GMO, the new combination of genetic material must first be constructed by using enzymes (proteins that catalyze reactions in organisms) to cut and join DNA from different sources into one stretch. To make a GM plant, say, that has a built-in insecticide to kill insect pests, for example, a gene coding for a protein that kills the insect is included, along with signals to enable it to be read by the cell to make the protein, a start signal referred to as promoter, and a stop signal, terminator. This is known as an 'expression cassette', a unit construct (Figure 2).

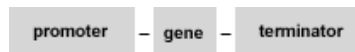


Figure 2. An expression cassette

Often, more than one expression cassettes are linked (or stacked) together, and the whole construct is spliced into a *plasmid*, a parasitic piece of DNA in bacteria that multiplies independently of the chromosome, so that the construct can be copied millions to tens of millions of time. The copies are then introduced into the cells or embryos or an organism, such as maize or mouse, so that the construct can be inserted into the cell's genome. Geneticists use either mechanical means to force the foreign constructs into the cells, or else they splice the genes into a vector which then smuggle them into the cells (see Fig.3).

Mechanical means include injection with a fine glass pipette in the case of mouse embryos, or particle bombardment, in which fine particles of gold or tungsten are coated with the DNA construct and fired into the cells with a 'gene gun'. Or else strong electric fields could be used to create pores in the cell membrane letting in the foreign DNA. These usually cause a lot of damage to the cells.

Vectors or gene carriers are made from viruses or bacteria that are adept at getting into cells. The construct is spliced into the vector, which smuggles it into the cell.

Within the cell, the vector carrying the construct, or the construct itself, becomes inserted into the genome.

There are key features of the process that makes it unpredictable and unreliable.

The process of insertion is uncontrollable and entirely random. The genetic engineer cannot yet target the insert to a specific site in the genome, nor preserve the intended structure of the insert itself. This results in many unpredictable and unintended effects. Depending on where in the genome and in what form the foreign genetic material is inserted, the resultant GMO will have distinctly different properties. The insert could jump into a gene of the host and disrupt its function, or the strong promoter signals in the construct could lead to inappropriate over-expression of host genes.

Plasmid vector with
antibiotic resistance gene



In order to select and identify those cells that have taken up the insert, genetic engineers use *antibiotic resistance marker genes* that are stitched next to the genes to be

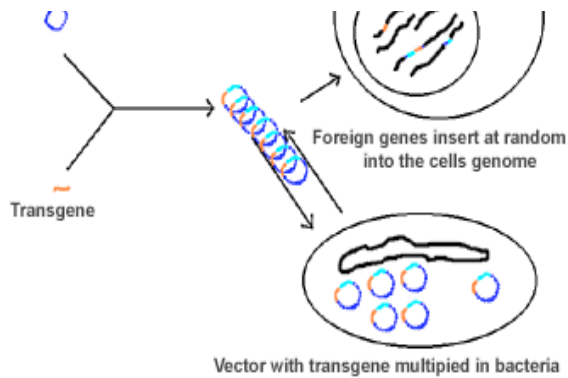


Figure 3. How to make a GMO

to grow into a GM plant, which, in theory should have the same foreign insert in everyone of its cells.

Unfortunately, the artificial constructs contain a lot of weak links and have proven to be unstable. There are, up to now, no data supporting the genetic stability of any transgenic line that has been produced.

For more on transgenic instability, read "The best kept secret of GM crops", ISIS Report, February 2002, also many other reports in *Transgenic Instability*, ISIS Reprints, ISIS Members website.

6. How does a GMO differ from one that is derived from conventional breeding?

In conventional breeding by reproduction, only individuals from the same species or related species can be mated to produce offspring. The offspring will have genes from both parents, but the genes are just different variants of the same genes coding for the same functions. A GMO, however, bypasses reproduction altogether, so completely new genes with new functions, as well as new combinations of genes can be introduced, which will interact with the organism's own genes in unpredictable ways.

Conventional breeding involves crossing many individuals of one variety or species with another. The result is a population that preserves much of the initial genetic diversity of the parental lines, and selection occurs in successive generations until the desired results are achieved. It is therefore more controllable and predictable.

A transgenic line, in contrast, results from gene insertion events in a single original cell, out of which the entire line is produced. It is genetically very impoverished.

Furthermore, the genetic engineering process for making the GMO is uncontrollable and error-prone (see above), it causes random disturbances to the system, making the result highly unpredictable as well as unstable. Genetic instability of GMOs is now a well-known problem. GM crops are failing and GM animals have had little success.

7. Is GM food safe to eat and safe for the environment?

There are reasons to be very cautious about the safety of GM food.

New genes and gene products, mostly from bacteria, viruses and other non-food species are being introduced that we have never eaten before, at least not in such quantities. They may be toxic or may cause allergic reactions.

These new genes and gene products may also harm other organisms that interact with the GM crops.

The vast majority of GM crops are engineered to be tolerant to broad-spectrum herbicides that not only kill all other plants, but also known to be toxic for wild animals and human beings.

The transgenes and antibiotic resistance marker genes may spread out of control, not just through crossing with unrelated species, but through the transgenic DNA being taken up by unrelated species, including domestic animals and human beings eating the food. This is referred to as horizontal gene transfer (see below).

For more on this topic, read "Special safety concerns of GMOs" in *Hazards of GM Crops*, ISIS Reprints, [ISIS members website](#).

8. What is horizontal gene transfer, and why is it dangerous?

A cell can pick up pieces of genetic material directly from its environment, and instead of digesting it as food, ends up inserting the genetic material into its own genome. The genetic material picked up could belong to the same species or to unrelated species. This 'illicit' gene trafficking is called *horizontal* gene transfer, to distinguish it from the vertical transfer that takes place in reproduction.

inserted, so by using antibiotics, only the cells that have taken up the foreign insert will survive.

In the case of an embryo that has the foreign construct inserted into the genome of some of its cells, it will grow into an organism carrying the foreign genes in some of its cells. And by subsequent breeding, a GMO can be obtained which, theoretically at least, carries the same foreign genes in every one of its cells. In the case of plant cells that have taken up the foreign insert, each cell can be stimulated

Horizontal gene transfer across species barriers is a rare event in nature, especially in multi-cellular organisms. Foreign genetic material is largely broken down or otherwise put out of action. And even after it has become inserted into the genome, it can still be thrown out.

Genetic engineering consists to a large extent, of *artificial* horizontal gene transfer. New combinations of genetic material from different species are made (recombined) in the laboratory. The artificial constructs are designed to cross all species barriers and to jump into genomes. They are also structurally unstable, consisting of many weak links, and tend to break and rejoin incorrectly, or to join up with genetic material from other genomes. In other words, the process of genetic engineering has greatly enhanced the potential for uncontrolled horizontal gene transfer.

Horizontal transfer of transgenic DNA could create new disease-causing viruses and bacteria, spread antibiotic resistance genes to the pathogens to make the diseases untreatable. Insertion of foreign DNA into animal cells could also trigger cancer.

For more details on this topic, read, "What is horizontal gene transfer" and "Techniques and dangers of genetic engineering" in Horizontal Gene Transfer, ISIS Reprints in [ISIS members website](#).



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