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NF04-591 What is Genetic Engineering and How Does it Work?

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What is Genetic Engineering and How Does it Work?

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What is Genetic Engineering?

Genetic engineering is the process of manually adding new DNA to an organism. The goal is to add one or more traits not already found in that organism. Examples of genetically engineered (transgenic) organisms include plants with resistance to specific insects, plants that can tolerate herbicides, and crops with modified oil content in their seeds.

Understanding Genetic Engineering: Basic Biology

To understand how genetic engineering works, there are a few key biology concepts about living things that must be understood.

Concept 1: What is DNA?

DNA is the recipe for life. DNA is a molecule found in the nucleus of every cell. It consists of a chain of four subunits represented by the letters A, T, G, and C. The order of these subunits in the DNA chain holds a code of information for the cell. Just like the English alphabet makes up words using 26 letters, the genetic language uses 4 letters to spell out the instructions for how to make the proteins an organism will need to grow and live.

Small segments of DNA are called genes (*Figure 1*). Each gene holds the instructions for how to produce a single protein. A gene can be compared to a recipe for making food. Each recipe is a set of instructions for making a single specific dish.

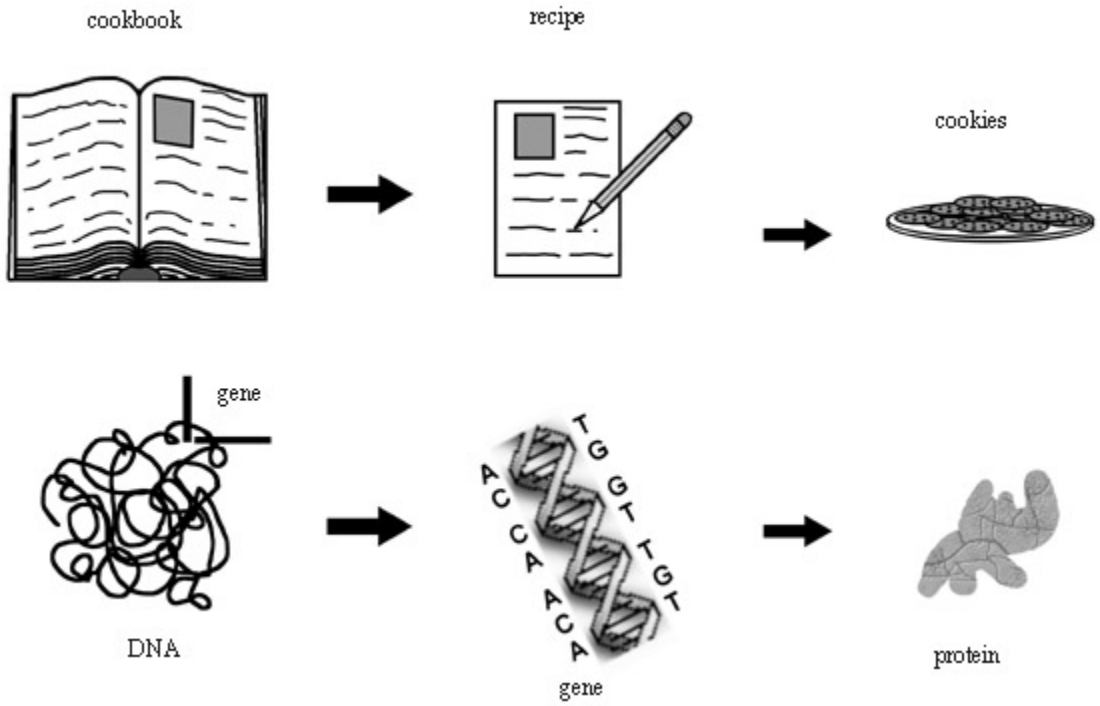

Figure 1. A gene is a small segment of DNA that contains the instructions for producing a single protein, much as a recipe from a cookbook contains the instructions for preparing a single dish.

An organism may have thousands of genes (*Figure 2*). The set of all genes in an organism is called a genome. A genome can be compared to a cookbook of recipes that tells how to make that organism what it is. Every living organism has a different cookbook, except identical twins and clones. Every cell in an organism has a copy of the cookbook of instructions.

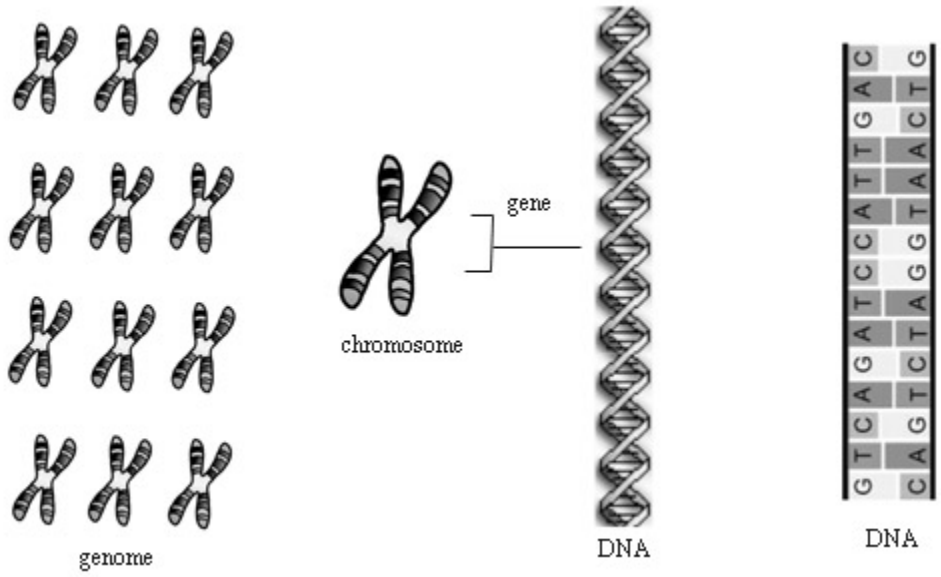

Figure 2. An organism may have thousands of genes, each of which is a small segment of the organism's DNA. DNA is a chain of four subunits called nucleotides represented by the letters A, G, T, and C. The sequence of nucleotides in the DNA code of a gene

specifies how amino acids should be linked together to form a single protein. The set of all genes in an organism is called a genome.

Concept 2: Why are proteins important?

Proteins are the building blocks of all living things. They do the work in the cells in three ways:

1. Proteins can be part of structures (such as cell walls, ribosomes, etc).
2. Proteins can regulate reactions that occur in the cell.
3. Proteins can serve as enzymes, which speed-up reactions.

Everything in an organism is either made of proteins or is the result of a protein's action.

Concept 3: DNA uses a universal language.

If all cookbooks around the world were written in a single language that everyone knew, recipes could be easily shared with anyone. DNA is a "universal language" in that the genetic code means the same thing in all organisms. This characteristic is critical to the success of genetic engineering. Genes can be transferred across species and still work (Figure 3).

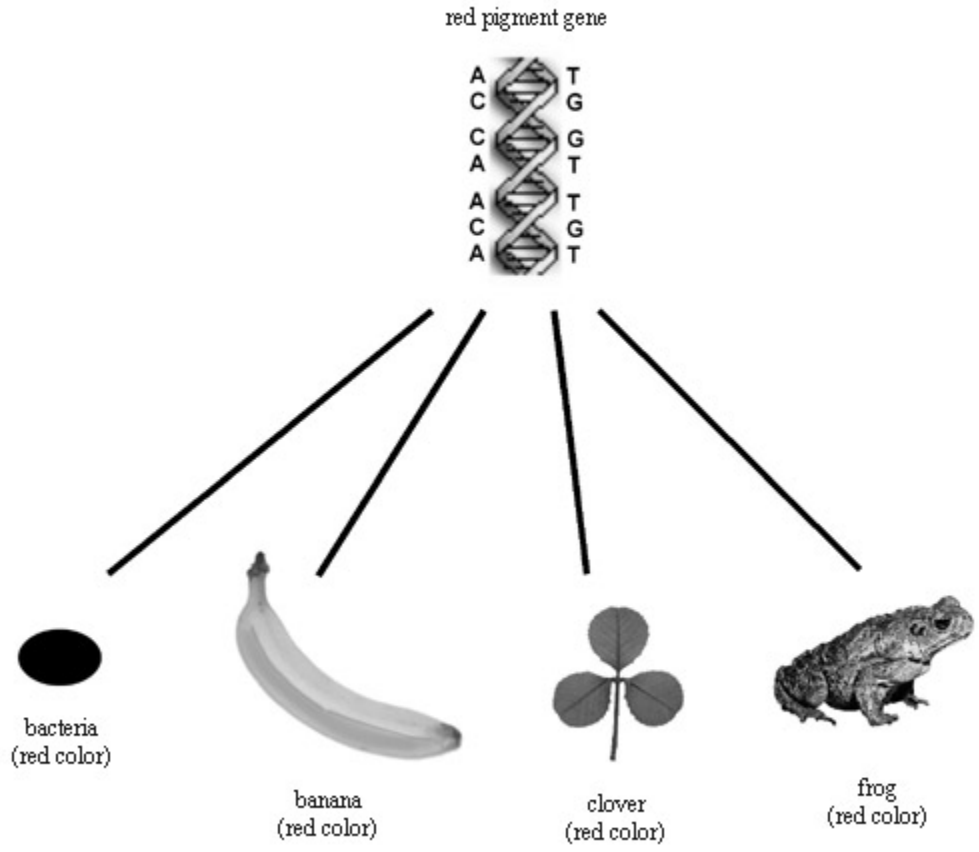

Figure 3. A copy of a gene for a specific trait can be removed from one organism and

added to a variety of organisms, giving them the ability to express that trait.

How is Genetic Engineering Done?

Genetic engineering, also known as transformation, works by obtaining a gene from the genome of one organism and inserting it into the genome of another. This gives the recipient organism the ability to express the trait encoded by that gene. It is like taking a single recipe out of one cookbook and placing it into another cookbook.

The Genetic Engineering Process

Once a goal is in mind...

1. Find an organism that naturally contains the desired trait.
2. The DNA is extracted from that organism. This is like taking out the entire cookbook of recipes (*Figure 4*).

Figure 4. A red apple has a red pigment gene. The DNA including the red pigment gene is extracted from the apple.

3. From the thousands of genes that were extracted from the donor organism, the one desired gene (recipe) must be located and copied. This is called gene cloning.
4. The gene may be modified prior to insertion. For example, the on/off switch of the gene may be replaced so that the gene will work in a more desirable way once inside the recipient organism.
5. The new gene(s), called a transgene, is delivered into cells of the recipient organism. The most common transformation technique in plants uses a bacterium. This bacterium has the capability of naturally genetically engineering host plants with its own DNA. The transgene is inserted into the bacteria, which then delivers it into single cells from the plant being engineered. Another technique, called the gene gun method, shoots microscopic gold particles coated with copies of the transgene into single cells of the recipient organism. With either technique, transgenic cells are induced to develop into entire plants. Genetic engineers have no control over where or if the transgene inserts into the genome. As a result, it takes hundreds of attempts to produce just a few transgenic organisms.
6. Once a transgenic organism has been created, traditional breeding is used to improve the characteristics of the final product. Genetic engineering does not eliminate the need for traditional

breeding. It is simply a way to add genes that control new traits to the gene pool of that organism.

How Does Genetic Engineering Compare to Traditional Breeding?

Although the goal of both genetic engineering and traditional plant breeding is to improve an organism's traits, there are some key differences between them. While genetic engineering manually moves genes from one organism to another, traditional breeding moves genes through mating the organisms in hopes of obtaining offspring with the desired combination of traits.

Breeding is also less precise than genetic engineering. In breeding, half of the genes from each parent are passed on to the offspring. This may include many genes for traits that are not wanted in the new organism. Genetic engineering, however, directs the movement of a single or limited number of genes.

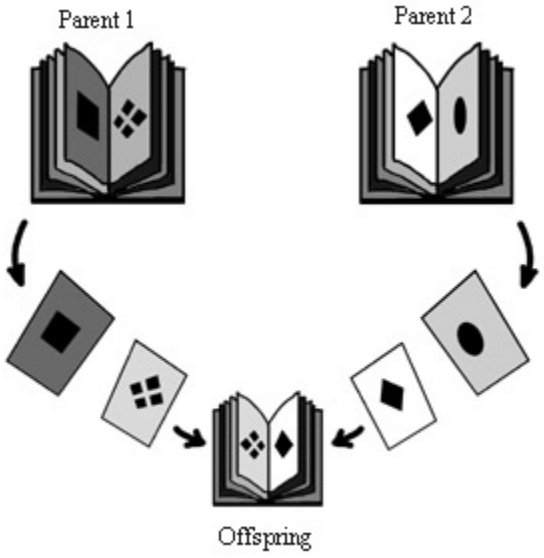

Figure 5. With traditional plant breeding, half of the genes from each parent plant are shared with the offspring. The process can be compared to randomly combining half the recipes (or genes) from one cookbook with recipes from another cookbook to develop a whole new cookbook incorporating some of the recipes from each. This process is less precise than that used for genetic engineering.

Using the recipe analogy, traditional breeding is like taking two cookbooks and randomly combining recipes from each into one cookbook. The product is a new cookbook with half of the recipes from each original book. Therefore, in crossing, half of the genes in the offspring of a cross come from each parent (*Figure 5*). Genetic engineering is like moving a single recipe from one cookbook to another (*Figure 6*).

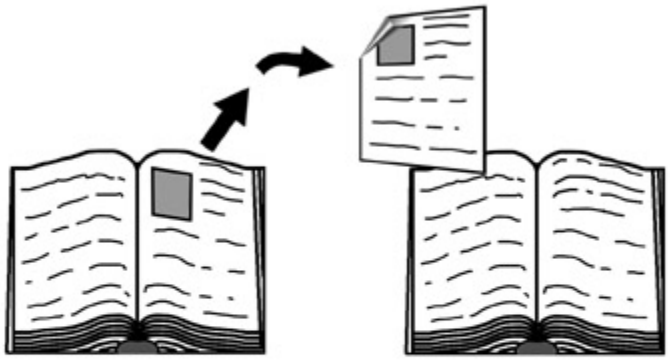

Figure 6. With genetic engineering, one (or just a few) genes are moved from one organism to another.

Traditional breeding is effective in improving traits, however, when compared with genetic engineering, it does have disadvantages. Since breeding relies on the ability to mate two organisms to move genes, trait improvement is generally limited to those traits that already exist within that species.

Genetic engineering, on the other hand, physically moves the genes from one organism and places them into the other. This eliminates the need for mating and allows the movement of genes between organisms of any species. Therefore, the potential traits that can be used are virtually unlimited.

Summary

Genetic engineering of plants has some distinct differences from traditional plant breeding. In many cases, these differences provide advantages in developing plants that meet the needs of people.

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