Molecular aspects of biotechnology (scope- Modern biotechnology in detail)

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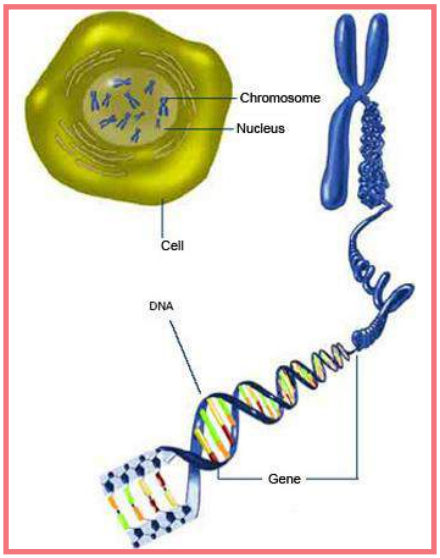
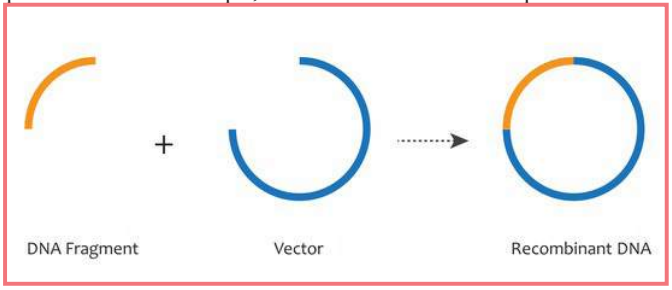
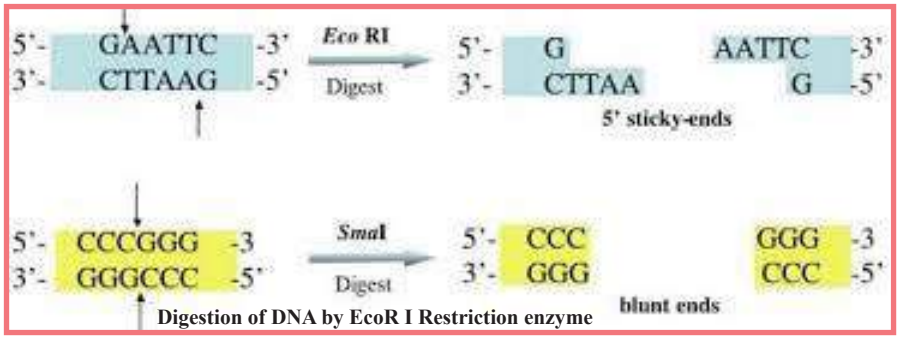
Biotechnology is the use of living organisms and their components to solve problems or make useful products. This is not a novel technology. Since ancient times this technology had been used by humankind in agriculture, food production and medicine, and that is called traditional biotechnology or conventional biotechnology. However, the discovery of DNA and genes in the 1950's opened the path to a new era of biotechnology called modern biotechnology. The alternation of genetic material in an organism (a plant, an animal or a microorganism) using recombinant DNA technology is called modern biotechnology. Combining the DNA of one organism with the DNA of another organism is called recombining of DNA, and all the techniques that use to recombining DNA is called recombinant DNA technology. Recombinant DNA technology was first introduced in the 1970's with bacteria, and this is also known as "gene cloning" or "genetic engineering", which offers potentially unlimited opportunities for creating new combinations that does not exist under natural conditions. Hence, using this technique, the genes in living organisms can be altered, and the organisms thus produced are called genetically modified organisms (GMOs) or living modified organisms (LMOs).



Biotechnology, through genetic engineering, works directly with the genetic material of a cell. If one examines a cell under a high-powered microscope, one would see long, thread-like structures called chromosomes. These chromosomes, composed of DNA (deoxyribonucleic acid), are organized into sections called genes. Genes control the production of particular proteins, and these proteins, in turn, determine the characteristics of an organism. In some cases, a gene may govern one particular trait, such as an organism's resistance to disease, while in other cases, characteristics may be determined by many genes. Therefore, by changing genes in a precise and controlled manner, it is possible to produce the desired changes in the characteristics of the organism. The knowledge gained on this has allowed researchers to transfer genes between the cells of different organisms. The foreign DNA or gene is introduced into the genome of the recipient organism (host) in such a way that the total genome of the host is unchanged except for the single manipulated gene. Thus, DNA can be isolated from a cell of plants, animals or microorganisms (the donors), and be fragmented into groups of

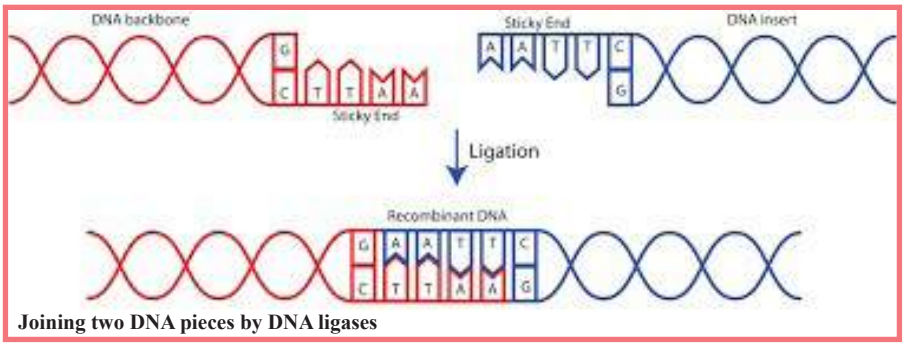




Digestion of DNA by EcoR I Restriction enzyme

one or more genes. Such fragments or genes can then be combined to another piece of DNA called the vector, and then passed into the host or recipient cell. The vectors are also called plasmids, which are small naturally occurring circular segments of DNA present in bacterial cells. Plasmid DNA can be taken outside of the bacterial cell, modified with the addition of a new gene, and replaced in the bacterial cell. With the new gene, the bacterial cell can now manufacture the product of the gene as its own. Because bacteria reproduce very rapidly, large volumes of bacteria containing the modified plasmid can be used to produce commercially significant quantities of a gene product, such as a food additive or an animal vaccine, in short periods of time. Hence, genetic engineering will enable the breeder to select the particular gene required for a desired characteristic, modify it, and transfer it to another organism.

The actual transfer of a gene between two organisms is carried out in a complex "cut and paste" procedure. Let's see, how it is possible to make animal protein (eg: insulin) in bacterial cells using this "cut and paste" procedure, in the same manner that was introduced above as the recombinant DNA technology. First, the gene which encode the insulin hormone should be identified and isolated from the

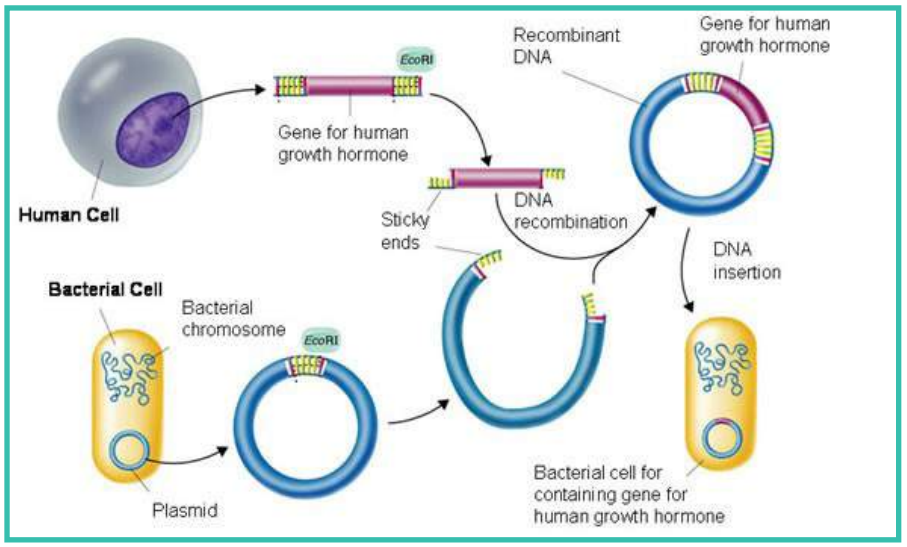


Joining two DNA pieces by DNA ligases

animal genome. Then the gene should be introduced into a cut vector before transforming into bacterial cells. Specialized enzymes that are used to cut vector DNA or DNA are called restriction enzymes. To paste or ligate the gene with cut vector, the edges of the both gene and the cut vector should be compatible. To make both edges of the gene and the cut vector compatible, both should be digested with the same restriction enzyme. Then they can be ligated together to form recombinant DNA molecule by the enzyme called DNA ligases. The ligated vector with the insulin gene cannot propagate outside of the living cells, and must be introduced into the bacterial cell to produce the desired animal protein in bacterial cells.

Not only bacterial cells, but also plant and animal cells can be used to transform genes to produce transgenic plants and transgenic animals. However, the techniques used to transform animal and plant cells are not the same as that used in bacterial transformation. Some of the techniques used in animal and plant transformations are microinjection, gene gun or particle bombardment, *Agrobacterium* mediated transformation and protoplast transformation. Among these techniques, the technique called micro-injection is the method often used to produce genetically engineered or transgenic animals. Through this technique, a very fine needle is used to inject a solution of DNA molecules containing genes that carry desired characteristics (such as disease resistance) into animal cells, usually at the embryo stage. The genes are incorporated into the animal cells genetic material, and the cells begin to express the characteristic determined by the new gene. Applying this micro-injection technique could have potential benefits for agriculture as well.

Plant cells have tough outer walls, making the delivery of genes into the plant cells a little more challenging than is the case for bacteria and animal cells. There are two main techniques by which this process is carried out. The first technique involves the use of a modified species of bacterium called *Agrobacterium*. In nature, the *Agrobacterium* invades a plant, then infects it with a segment of its own DNA that "codes" for the development of crown gall disease.



This DNA is incorporated into the plant's DNA and the plant becomes diseased with crown gall. When using *Agrobacterium* to genetically modify plants, these disease-causing parts of the *Agrobacterium*'s DNA are removed. They are replaced with genes that carry desired characteristics (such as improved nutritional value) by the "cut and paste" procedure. The *Agrobacterium* can then be introduced to plant cell material, where it can invade plant cells, and introduce the new gene with the desired characteristics. The full plants grown from these plant cells express the characteristic determined by the new gene. *Agrobacterium,* therefore, is a convenient delivery system by which new characteristics can be passed on to plants. The second technique used to deliver genetically engineered DNA into plants is the DNA "particle bombardment or gene gun" method. Tiny metal particles coated with genes with desired characteristics, such as improved nutritional value, are put into a particle gun and fired directly into plant cells. These genes are incorporated into the plant cell's DNA, and the cells are then grown into full plants. The new characteristic is thereafter present in the whole plant. These techniques have been used to introduce gene with special characters to plants and animals to produce transgenic plants and animals in a variety of fields; agriculture, medicine, pharmacology, environment etc. Let's take one example to see how modern biotechnology has been used in plant protection.

Crops plants such as corn, cotton, and potato have been successfully transformed through genetic engineering to make a protein that kills certain insects when they feed on the plants. The protein was isolated from the soil bacterium *Bacillus thuringiensis,* which has been used for decades as the active ingredient of some "natural" insecticides. In some cases, an effective transgenic crop-protection technology can control pests better and more cheaply than existing technologies. For example, with Bt engineered into a corn crop, the entire crop is resistant to certain pests, not just the part of the plant to which Bt insecticide has been applied. In these cases, yields increase as the new technology provides more effective control. In other cases, a new technology is adopted because it is less expensive than current technology. There are cases in which new technology is not adopted because for one reason or another it is not competitive with the existing technology. For example, organic farmers apply Bt as an insecticide to control insect pests in their crops, yet they may consider transgenic Bt crops to be unacceptable.

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