



Recombinant DNA Technology and Its Role in Modern Biotechnology

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DESCRIPTION

Recombinant DNA technology, often referred to as genetic engineering, is one of the most influential scientific developments of the 20th century. It enables scientists to manipulate genetic material by combining DNA from different sources, thereby creating new genetic combinations that do not occur naturally. This technology has revolutionized medicine, agriculture, industry, and research, providing tools to better understand biological systems and develop solutions to global challenges.

The foundation of recombinant DNA technology lies in understanding the structure and behavior of DNA. Every living organism stores its hereditary information in DNA molecules composed of nucleotide sequences. Recombinant DNA methods take advantage of the universality of this genetic code, meaning DNA from one organism can be inserted into another and still function. This concept allows scientists to transfer genes with desired traits across species boundaries.

One of the key steps in recombinant DNA technology is the use of restriction enzymes, molecular scissors that recognize and cut DNA at specific sequences. These cuts create short single-stranded overhangs known as sticky ends, which can be joined with complementary sequences from another DNA source. Once the desired gene is isolated, scientists use DNA ligase to seal the pieces together, forming a stable recombinant DNA molecule.

The next stage typically involves introducing the recombinant DNA into a host organism. This is often achieved using vectors, such as plasmids, bacteriophages, or artificial chromosomes. Plasmids, which are circular DNA molecules found in bacteria, are especially popular due to their stability and ease of manipulation. After the recombinant plasmid is inserted into a bacterial cell through a process called transformation, the bacteria replicate rapidly, producing many copies of the inserted gene.

Recombinant DNA technology has had profound impacts on medicine. One of the earliest and most notable achievements

was the production of recombinant human insulin. Before gene technology, insulin was extracted from animals, which was costly and sometimes caused allergic reactions. By inserting the human insulin gene into bacteria, researchers enabled the microorganisms to produce insulin identical to the human form, which greatly improved diabetes treatment. Today, recombinant technology is used to create vaccines, growth hormones, clotting factors for hemophilia, monoclonal antibodies, and even advanced gene therapies.

In agriculture, recombinant DNA has produced genetically modified crops with improved traits such as pest resistance, enhanced nutrition, drought tolerance, and increased yield. For example, Bt cotton contains a gene from the bacterium *Bacillus thuringiensis*, enabling the plant to produce proteins toxic to certain insect pests. This reduces the need for chemical pesticides and increases crop productivity. Golden Rice, enriched with vitamin A, demonstrates how recombinant methods can address nutritional deficiencies affecting millions worldwide.

Recombinant DNA also plays a critical role in scientific research. By inserting genes into model organisms like bacteria, yeast, or mice, researchers can study gene function, protein interactions, and disease mechanisms. This technology has paved the way for breakthroughs in molecular biology, genomics, and synthetic biology, where scientists design new biological systems from scratch.

Despite its benefits, recombinant DNA technology raises ethical, environmental, and safety considerations. Concerns include the potential release of genetically modified organisms into ecosystems, the long-term effects of GM foods, and the moral implications of genetic manipulation. For this reason, strict regulatory frameworks and biosafety guidelines govern its use worldwide.

In Conclusion, Recombinant DNA technology has transformed modern science by enabling precise manipulation of genetic material, leading to innovations in medicine, agriculture, and research. Its ability to create organisms with beneficial traits, produce vital therapeutic products, and uncover fundamental

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biological processes highlights its immense value. As the field continues to evolve, recombinant technology remains a cornerstone of biotechnology, shaping future advancements

while prompting ongoing discussions about ethics, safety, and responsible use.