Biotechnological Applications of Recombinant DNA

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1.0 November 2024

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Objectifs

Recombinant DNA technology has proven important in producing vaccines and protein therapies such as human insulin, interferon and human growth hormone. Overall, this course aims to highlight and provide students with a comprehensive understanding of the techniques, principles, and applications of recombinant DNA technology in genetic engineering to address societal needs, improve human health, enhance food and energy production, and promote sustainable development. By the end of the course, students will be able to:

- Explain the fundamental concepts of recombinant DNA technology, including gene cloning, DNA manipulation, and genetic engineering techniques.
- Understand the significance of recombinant DNA technology in various fields such as medicine, agriculture, industry, and environmental science.
- Analyze and interpret results data generated through recombinant DNA techniques, and critically evaluate the validity and significance of research findings.
- Apply knowledge of recombinant DNA technology to solve practical problems and design experiments in biotechnology research and development.
- Assess current advancements and emerging trends in biotechnological applications of recombinant DNA.
- Communicate effectively about recombinant DNA technology concepts, research findings, and applications through written reports, oral presentations, and scientific discussions.

Introduction

What do you think of when you hear the word **"biotechnology"?** Maybe things you've seen in the news, such as Dolly the cloned sheep, genetically modified organisms, or gene therapy. If that's what you think of, you're absolutely right: these are all examples of biotechnology. But what about crop breeding and the antibiotic penicillin? These processes and products – some of which have been around for thousands of years – are also examples of biotechnology.

What is biotechnology?

Biotechnology is the use of an organism, or a component of an organism or other biological system, to make a product or process for a specific use. This is a very broad definition, and as mentioned above, it can include both cutting-edge laboratory techniques and traditional agricultural and culinary techniques that have been practiced for hundreds of years *[1]*[1]*. Let's look at three examples of biotechnology and see how they fit the definition:

Genetically Modified Crops (GMOs), also known as genetically engineered crops, are plants that have had their genetic material altered in a way that does not occur naturally through mating or natural recombination. This genetic modification is typically done in a laboratory to introduce specific traits or characteristics into the crops. These traits can be derived from other plants, animals, bacteria, or even synthetic sources.

Penicillin: The antibiotic penicillin is generated by certain molds. To make small amounts of penicillin for use in early clinical trials, researchers had to grow up to 500 liters of "mold juice" a week. The process has since been improved for industrial production, with use of higher-producing mold strains and better culture conditions to increase yield. Here, we see an organism (mold) being used to make a product for human use – in this case, an antibiotic to treat bacterial infections.

Gene therapy: Gene therapy is an emerging technique used to treat genetic disorders that are caused by a nonfunctional gene. It works by delivering the "missing" gene's DNA to the cells of the body. For instance, in the genetic disorder cystic fibrosis, people lack function of a gene for a chloride channel produced in the lungs. In a recent gene therapy clinical trial, a copy of the functional gene was inserted into a circular DNA molecule called a plasmid and delivered to patients' lung cells in spheres of membrane (in the form of a spray).

What is DNA technology?

Many examples of modern biotechnology depend on the ability to analyze, manipulate, and cut and paste pieces of *DNA*∗. Approaches for the sequencing and manipulation of DNA are sometimes referred to as DNA technology. For example, for the cystic fibrosis gene therapy trial, researchers used DNA manipulation techniques to insert the chloride channel gene into a piece of carrier DNA (a vector) that allowed it to be expressed in human lung cells.

DNA technology is important to both basic and applied (practical) biology. For instance, a technique used to make many copies of a DNA sequence, called[2] *polymerase chain reaction*∗ (PCR) *[2]*[2]∗, is used in many medical diagnostic tests and forensics applications as well as in basic laboratory research.

2. https://www.khanacademy.org/science/biology/biotech-dna-technology/dna-sequencing-pcr-electrophoresis/a/polymerase-chain-reaction-pcr

What is recombinant DNA?

Recombinant DNA is a form of artificial DNA that is made through the combination or insertion of one or more DNA strands, therefore combining DNA sequences as per your requirement, within different species, as shown in the figure 1.

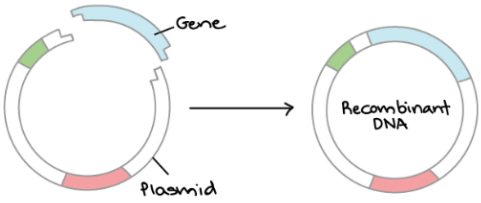


Figure 1. Illustrative image of Recombinant DNA technology

Recombinant DNA, also known as genetic engineering, is the process of combining DNA from different organisms to create a new and potentially useful organism *[3]*[3]*. Here are the general steps for recombinant DNA in Figure 2:

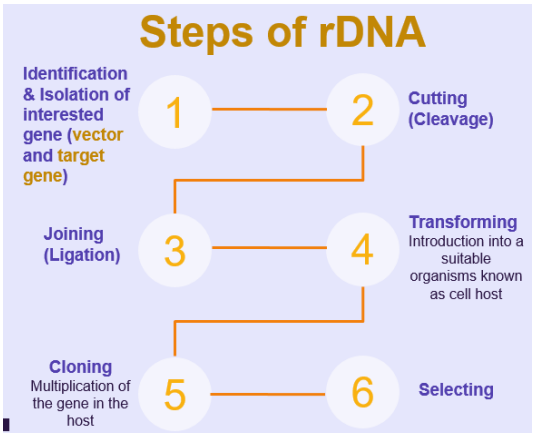
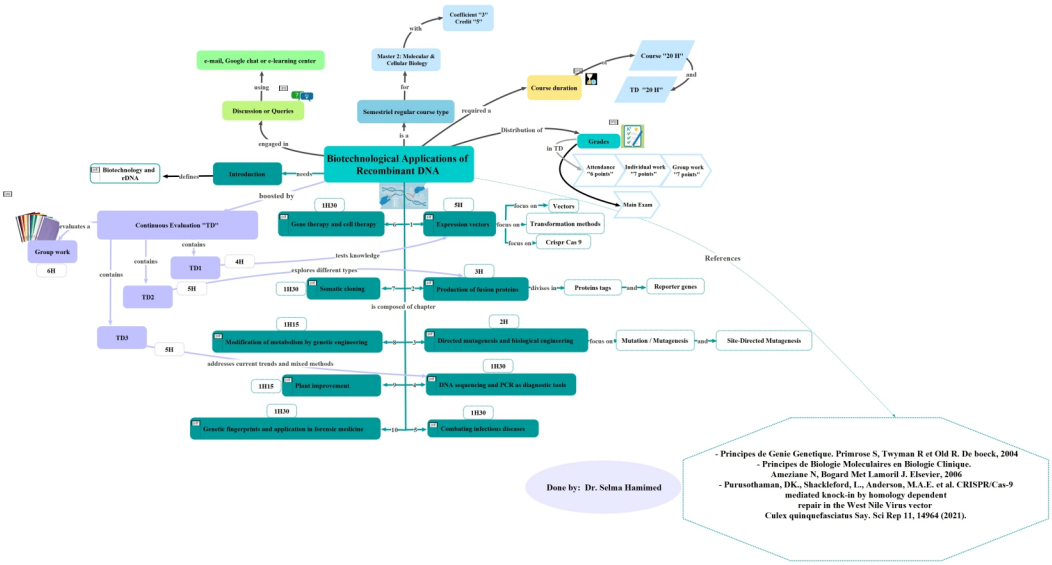


Figure 2. Overall steps for recombinant DNA

Advantages of Recombinant technology:

- Provide substantial quantity;
- No need for natural or organic factors;
- Tailor made product that you can control;
- Unlimited utilizations;
- Cheap;
- Resistant to natural inhibitors.



Graphique 1 Figure 3. Mental map

I Prerequisites

- Strong foundation in molecular genetics and genomics, including gene structure, regulation, and expression.
- Knowledge of genomic organization and analysis techniques is also essential.
- Understanding of biochemistry and cell biology: Familiarity with biochemical processes, cell structure, and cellular functions is crucial for comprehending the applications of recombinant DNA technology at the molecular and cellular levels.
- Knowing how to perform DNA extraction, gel electrophoresis, PCR, cloning, and bacterial transformation would help.
- Basic proficiency in data analysis and bioinformatics tools.

Exercice 1 : How is gene structure defined?

[solution n°1 p. 8]

Gene structure characteristics?

- ☐ The arrangement of exons and introns within a gene
- ☐ The location of a gene on a chromosome
- ☐ The arrangement of nucleotides in a DNA sequence
- ☐ The number of alleles present in a gene

Exercice 2 : What is the primary function of mRNA in gene expression?

[solution n°2 p. 8]

Transcription role?

- ○ Carrying amino acids to the ribosome
- ○ Acting as a template for DNA replication
- ○ Transferring genetic information from the nucleus to the cytoplasm
- ○ Initiating the translation process

Exercice 3 : Which of the following is an example of post-transcriptional gene regulation?

[solution n°3 p. 8]

Examples demonstrate post-transcriptional gene regulation?

- ☐ Alternative splicing
- ☐ DNA methylation
- ☐ Acetylation
- ☐ mRNA degradation

Exercice 4 : The regulation mechanism

[solution n°4 p. 8]

The lac operon is a gene regulatory system that the expression of genes involved in the of .

Exercice 5 : The steps in DNA extraction are:

[solution n°5 p. 9]

1. Washing
2. Precipitating DNA
3. Pelleting
4. Purifying DNA
5. Lysing cells

Réponse : ___ ___ ___ ___ ___

Solutions des exercices

Solution n°1

[exercice p. 6]

Gene structure characteristics?

- [x] The arrangement of exons and introns within a gene
- [ ] The location of a gene on a chromosome
- [x] The arrangement of nucleotides in a DNA sequence
- [ ] The number of alleles present in a gene

Solution n°2

[exercice p. 6]

Transcription role?

- ○ Carrying amino acids to the ribosome
- ○ Acting as a template for DNA replication
- ◉ Transferring genetic information from the nucleus to the cytoplasm
- ○ Initiating the translation process

Solution n°3

[exercice p. 6]

Examples demonstrate post-transcriptional gene regulation?

- [x] Alternative splicing
- [ ] DNA methylation
- [ ] Acetylation
- [x] mRNA degradation

Solution n°4

[exercice p. 7]

The lac operon is a `bacterial` gene regulatory system that `controls` the expression of genes involved in the `metabolism` of `lactose`.

Solution n°5

[exercice p. 7]

Precipitating DNA | Washing | Lysing cells | Purifying DNA | Pelleting

The steps in DNA extraction

Glossaire

Polymerase chain reaction (PCR)

A method widely used to make millions to billions of copies of a specific DNA sample rapidly, allowing scientists to amplify a very small sample of DNA (or a part of it) sufficiently to enable detailed study.

Abréviations

DNA : Deoxyribonucleic acid ; is the molecule that carries genetic information for the development and functioning of an organism.

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