chapter 13

Genetics and Biotechnology

section 2 DNA Technology

MAIN Idea

Genetic engineering manipulates recombinant DNA.

What You'll Learn

- the difference between selective breeding and genetic engineering
- how genetic engineering can be used to improve human life

Before You Read

The tools that a chef uses to prepare food differ from the tools a mechanic uses to fix cars. On the lines below, describe a few of the tools you use at home and school. In this section, you will learn about tools scientists use to study DNA.

_____

_____

Mark the Text

Main Ideas As you read, underline or highlight the main ideas in each paragraph.

Read to Learn

Genetic Engineering

For many years, scientists knew the structure of DNA and knew that information flowed from DNA to RNA and from RNA to proteins. In the last few decades, scientists have learned more about how individual genes work by using genetic engineering. **Genetic engineering** is a way of manipulating the DNA of an organism by inserting extra DNA or inserting DNA from another organism.

One example of genetic engineering uses green fluorescent protein (GFP). GFP is a protein made naturally in jellyfish. GFP causes jellyfish to turn green under ultraviolet light. Scientists have inserted the DNA for making GFP into other organisms. This makes the organisms glow.

Reading Check

1. State What do scientists have to do to a gene before they can manipulate it?

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_____

DNA Tools

An organism's **genome** is all the DNA present in the nucleus of each cell. Genomes can contain millions of nucleotides in the gene's DNA. In order to study a specific gene, scientists isolate it from the rest of the organism's DNA. Scientists can then manipulate it. To understand how scientists do this, it is helpful to know the DNA tools scientists use.

What are restriction enzymes?

Scientists have found hundreds of restriction enzymes. **Restriction enzymes** are proteins made by bacteria. Each restriction enzyme cuts, or cleaves, DNA at a specific DNA sequence.

How do restriction enzymes work?

One restriction enzyme that is often used by scientists is called *EcoRI*. *EcoRI* cuts DNA containing the sequence GAATTC. After *EcoRI* cuts DNA, it leaves single-stranded ends, called *sticky ends*, as shown in the figure below. DNA that has been cut with *EcoRI* always has the same sticky ends. DNA fragments with sticky ends can be joined with other DNA fragments with complementary sticky ends.

Not all restriction enzymes leave sticky ends. Some restriction enzymes cut straight across both DNA strands, leaving blunt ends. DNA fragments with blunt ends can be joined to other DNA fragments with blunt ends.

How is gel electrophoresis used to separate DNA fragments?

After DNA is cut with a restriction enzyme, the DNA fragments are different sizes. Scientists use **gel electrophoresis** to separate DNA fragments according to the size of the fragments.

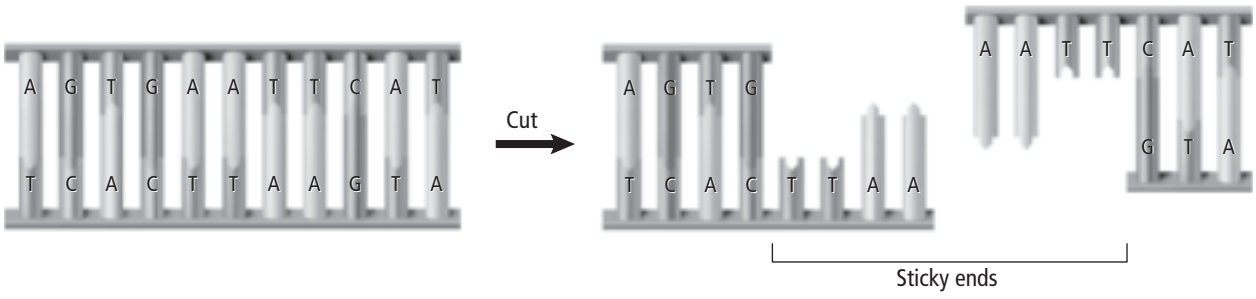
DNA fragments are placed on the negatively charged end of a material called gel. An electric current is applied to the gel. The DNA fragments move toward the positive end of the gel. Smaller fragments move through the gel faster than larger fragments. The unique pattern made by the DNA fragment can be compared to the patterns of known DNA fragments for identification. The figure below shows a gel in which DNA has been separated by electrophoresis.

Think it Over

2. Explain Why can two different fragments of DNA cut with *EcoRI* be joined?

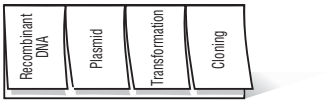
Picture This

3. Analyze Use the figure to explain to a partner how gel electrophoresis works.



FOLDABLES™

Take Notes Make a four-tab Foldable, as shown below. As you read, take notes and organize what you learn about recombinant DNA technology.



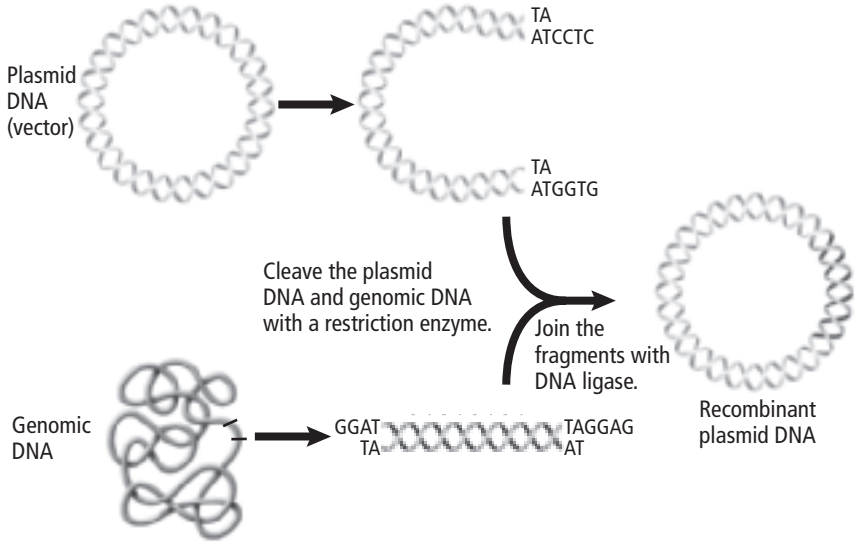
Picture This

4. Identify Circle the carrier in the figure.

Recombinant DNA Technology

Once DNA fragments have been separated using gel electrophoresis, fragments can be removed from the gel. These DNA fragments can then be combined with DNA fragments from another source, as shown in the figure below. This new DNA molecule, with DNA from different sources, is called **recombinant DNA**. Scientists use of recombinant DNA allows scientists to study individual genes.

Scientists often need to make a lot of recombinant DNA to study it. Scientists use host cells, such as bacteria, to copy the recombinant DNA. A carrier, known as a vector, is used to carry the recombinant DNA into the host cell. One commonly used vector is a small, circular, double-stranded DNA molecule called a **plasmid**. Plasmids can be cut with restriction enzymes. DNA fragments and plasmids cut with the same restriction enzyme can be combined at their sticky ends. An enzyme called **DNA ligase** is then used to join the plasmids and the DNA fragments chemically.



How does transformation occur?

Plasmid DNA can be moved into bacterial cells by **transformation**. Transformation occurs when bacterial cells are heated or given a small electric shock. This creates holes in the plasma membrane of the bacterial cell, enabling the plasmid DNA to enter the bacterial cell.

Plasmids are found naturally in bacteria. When the bacteria reproduce and copy their own DNA, they also copy the plasmid DNA. **Cloning** occurs when bacteria reproduce and copy recombinant DNA molecules.

What is DNA sequencing?

DNA sequencing involves finding out the exact order of the nucleotides that make up an organism's DNA. Knowing the DNA sequence of an organism gives scientists clues about how that organism's genes work. Scientists can compare genes from different organisms. Scientists can also find errors in the DNA. Long DNA molecules must be cut with restriction enzymes before they can be sequenced.

Reading Check

5. Determine How are restriction enzymes used?

How is DNA sequenced?

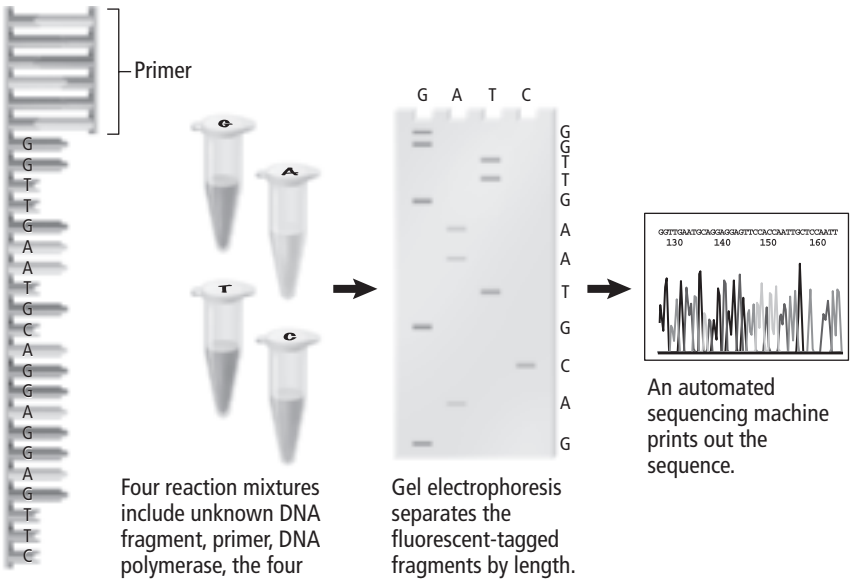
The figure below shows how DNA is sequenced. Scientists mix an unknown DNA fragment, DNA polymerase, and the four nucleotides—A, C, G, and T. Each of the four nucleotides are tagged with a different color of fluorescent dye.

What stops the growth of a DNA strand?

Usually, when DNA polymerase copies the DNA fragment it will put normal nucleotides on the growing strand. However, sometimes a fluorescent-tagged nucleotide will be added to the strand. Every time these tagged nucleotides are added, the new DNA strand stops growing. This produces DNA strands of different lengths. The tagged fragments are separated by gel electrophoresis. An automated DNA sequencing machine is used to detect the color of each tagged nucleotide. The sequence of the original DNA is determined from the order of the tagged fragments.

Picture This

6. Identify Which step in the process separates DNA fragments by length?



Four reaction mixtures include unknown DNA fragment, primer, DNA polymerase, the four nucleotides, and a different tagged nucleotide.

Gel electrophoresis separates the fluorescent-tagged fragments by length.

An automated sequencing machine prints out the sequence.

What is polymerase chain reaction?

Polymerase chain reaction (PCR) can be used to make millions of copies of a specific region of a DNA fragment. PCR is so sensitive that it can detect a single DNA molecule in a sample. With PCR, scientists can copy a single DNA molecule many times so they can study it.

PCR is a powerful tool used by scientists. Forensic scientists use PCR to identify suspects and victims of crimes. Doctors use PCR to detect diseases such as AIDS.

Reading Check

7. Explain Why is polymerase chain reaction used to make millions of copies of a DNA fragment?

What are the steps of PCR?

Follow the figure below as you read the steps of PCR.

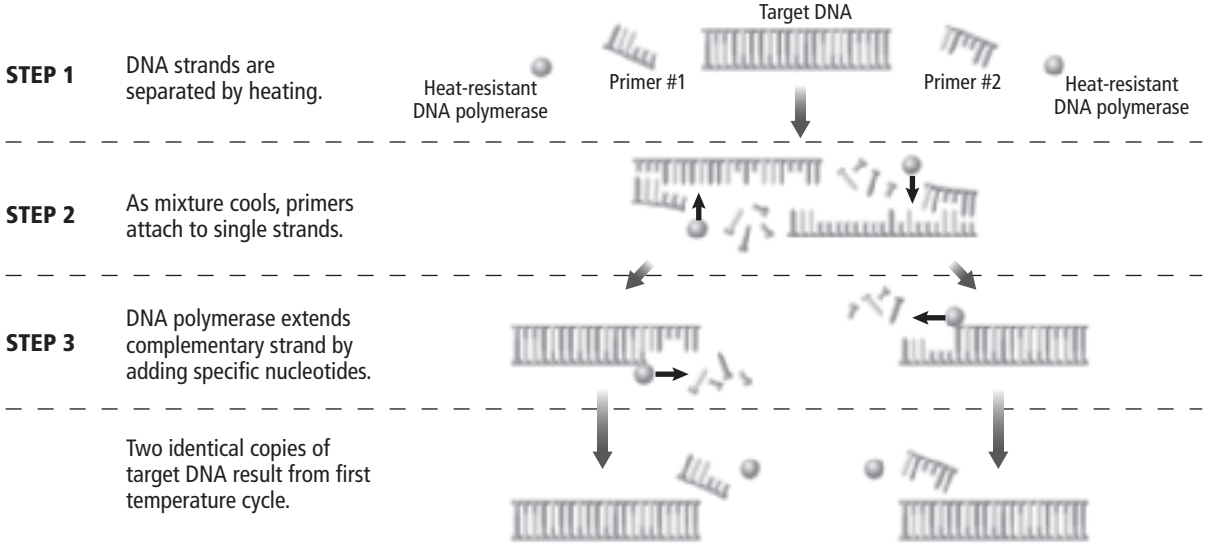
Step 1 Four things are mixed in a small tube: the DNA fragment to be copied, DNA polymerase, the four DNA nucleotides—A, G, C, and T—and two short, single-stranded pieces of DNA called primers. The primers are complements to the ends of the DNA fragment to be copied. The primers are used as starting points for the DNA copies.

Step 2 The tube is placed into a thermocycler. The thermocycler heats and cools the tube over and over again. When the tube is heated, the two strands of the DNA fragment separate. When the tube is cooled, the primers bind to the ends of the separated strands of the DNA fragment.

Step 3 Each primer binds to one strand of the DNA fragment. DNA polymerase then puts the correct nucleotides between the two primers making the copies. The DNA polymerase used in PCR must be able to withstand high heat. It comes from bacteria that live in hot springs, like the ones in Yellowstone National Park.

Picture This

8. Identify Underline the two starting points for the DNA copies.



Biotechnology

Biotechnology is the application of genetic engineering to human problems. Scientists can use biotechnology to produce transgenic organisms. **Transgenic organisms** are organisms that have a gene from a different organism inserted into their DNA. Transgenic animals, plants, and bacteria are used for scientific research, in agriculture, and to treat human diseases.

How are transgenic animals used?

Most transgenic animals are made in laboratories for biological research. Some commonly studied animals are mice, fruit flies, and roundworms. Scientists use these organisms to study diseases and develop ways to treat them.

Transgenic livestock are used to improve the food supply. They also are used to improve health in people. For instance, scientists have engineered goats to make a protein that stops blood from clotting. Surgeons use this protein during operations. Several species of fish have been genetically engineered to grow faster. In the future, transgenic animals might be used as a source of organs for organ transplants in people.

Reading Check

9. Identify one way scientists use transgenic animals.

How are transgenic plants used?

Transgenic crops are grown around the world. Farmers in at least 18 countries grow transgenic corn, soybeans, canola, and cotton on millions of acres. Farmers plant these crops because they are resistant to herbicides and insecticides. For example, scientists are now producing genetically engineered cotton. The cotton has been engineered to resist weevils, insects that harm cotton plants.

Scientists have developed other transgenic crops. They are testing these crops in fields. One of these crops is a transgenic rice that is more nutritious than normal rice. Scientists hope to use the transgenic rice to decrease malnutrition in Asian countries. Scientists are also testing crops that are designed to survive extreme weather.

Reading Check

10. Explain What is one trait scientists have engineered into transgenic plants?

Someday, peanuts and soybeans might be developed that do not cause allergic reactions. Transgenic plants might also be used to make vaccines or biodegradable plastics.

How are transgenic bacteria used?

Scientists use transgenic bacteria to make insulin, growth hormones, and other medical substances. Transgenic bacteria have been used to protect crops from frost damage and to clean up oil spills. Garbage in some landfills is being decomposed by transgenic bacteria.