Preview Key Concepts

9.1 Manipulating DNA
Biotechnology relies on cutting DNA at specific places.

9.2 Copying DNA
The polymerase chain reaction rapidly copies segments of DNA.

9.3 DNA Fingerprinting
DNA fingerprints identify people at the molecular level.

9.4 Genetic Engineering
DNA sequences of organisms can be changed.

9.5 Genomics and Bioinformatics
Entire genomes are sequenced, studied, and compared.

9.6 Genetic Screening and Gene Therapy
Genetics provides a basis for new medical treatments.

Review Academic Vocabulary

Write the correct word for each definition.

<table>
<thead>
<tr>
<th>allele</th>
<th>nucleotide</th>
<th>DNA polymerase</th>
<th>genome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Preview Biology Vocabulary

To see how many key terms you already know from this chapter, choose the word that makes sense in each sentence.

gene therapy   clone   bioinformatics

1. A genetically identical copy of a gene or organism is a ________________.

2. ________________ is the use of computer databases to organize and analyze biological data.

3. The replacement of a defective or missing gene is called ________________
Scientists use several techniques to manipulate DNA.

DNA is a large molecule, but it is still too small to see or to pick up with your hands. How can scientists work with DNA without being able to handle it directly? Chemicals, computers, and enzymes are just a few of the tools that are used in genetics research. For example, chemicals can be used to change, or mutate, a DNA sequence. Computers are used to organize large amounts of data from genetics research. Enzymes that come from bacteria are used to cut and copy pieces of DNA.

What are three tools used in genetics research?

Restriction enzymes cut DNA.

Recall that a chromosome is a long string of DNA that contains many different genes. To study just one gene, scientists cut apart DNA and separate out the different pieces. Some enzymes, called restriction enzymes, are like molecular “scissors” that cut apart DNA. A restriction enzyme cuts DNA at a specific nucleotide sequence. The place where a restriction enzyme cuts the DNA is called a restriction site. There are many different restriction enzymes. Each one cuts at a different restriction site. Two different restriction enzymes will cut the same strand of DNA in different ways.

Restriction enzyme 1 cuts the DNA strand in three places. Restriction enzyme 2 cuts the same strand of DNA in six places.

* ACADEMIC VOCABULARY

manipulate to work with and change, or alter, something
Some restriction enzymes cut straight across the DNA molecule, leaving “blunt ends.” Other restriction enzymes leave “sticky ends,” as shown in the figure below. A piece of DNA with sticky ends can join with another piece of DNA that has matching sticky ends because the base pairs are complementary. This feature makes sticky ends very helpful in genetics research.

**Restriction Enzymes Cut DNA**

Some restriction enzymes leave behind nucleotide tails, or “sticky ends,” when they cut DNA.

A restriction enzyme called TaqI cuts DNA when it finds its restriction site. TaqI’s restriction site is TCGA AGCT

**Instant Replay**

What are “sticky ends”?

**Restriction maps show the length of DNA fragments**.

After a piece of DNA is cut with restriction enzymes, the next step is to separate the different fragments. DNA fragments are separated according to their sizes by a process called **gel electrophoresis** (ih-LEHK-troh-fuh-REE-sih).

In gel electrophoresis, a segment of DNA is cut with a restriction enzyme into fragments of different lengths, as shown in the figure on the next page. The DNA sample, containing all the different fragments, is loaded into a thin piece of hard gelatin called a gel. The gel is placed into a machine that has a positive electrode at one end and a negative electrode at the other end. DNA molecules have a negative charge, so they are

* **ACADEMIC VOCABULARY**

  fragment  a smaller piece of a whole
attracted to the positive end. The fragments move through the gel in that direction after the electrical current is turned on. Then the different fragments from the sample are separated by size. Smaller pieces of DNA move through the gel faster than do the larger pieces. The distances the pieces of DNA travel can be used to estimate their sizes. The bands that show up on the gel do not give any information about the DNA sequence. They indicate only the length of the DNA.

Gel electrophoresis is used in many different parts of genetics research. For example, it can be used to diagnose genetic diseases by comparing the patterns of bands on a gel from an unknown sample of DNA with a known sample. The pattern of bands on a gel can be thought of as a map. This type of map is called a restriction map, and shows the lengths between each restriction site in a piece of DNA.

Which DNA fragment travels farther in a gel: large or small?

* ACADEMIC VOCABULARY

**electrode** the positive or negative end of electrical equipment

---

**9.1 Vocabulary Check**

| restriction enzyme | restriction map | gel electrophoresis |

Choose the correct term from the list for each description

1. cuts DNA at specific sequences ____________________________
2. tool that separates DNA fragments ____________________________
3. shows the sizes of DNA fragments between restriction sites ____________________________

**9.1 The Big Picture**

4. Circle the piece that would travel the farthest in gel electrophoresis. ____________________________
PCR uses polymerase to copy DNA segments*.

A scientist needs more than just a single piece of DNA or a single copy of a gene to study the DNA. To get a larger amount of DNA, the DNA is copied. **Polymerase chain reaction (PCR)** is a technique that produces millions, or even billions, of copies of a specific DNA sequence in just a few hours. Recall that DNA polymerase is a key enzyme in DNA replication. PCR also uses DNA polymerase to make copies of DNA—but in a test tube, not in a cell.

**PCR AMPLIFIES DNA SAMPLES**

Each PCR cycle doubles the number of DNA copies. The original piece of DNA becomes two copies. Those two copies become four copies—and the number doubles after each cycle.

After only 30 cycles of PCR, the original DNA sequence is copied more than a billion times. In this way, PCR can provide a large amount of a DNA sequence for study.

**What is PCR?**

**PCR is a three-step process.**

PCR uses four materials: the DNA to be copied, DNA polymerases, lots of each of the four DNA nucleotides—A, C, G, and T—and two primers. A **primer** is a short piece of DNA that acts as the starting place for a new strand. A primer is needed because DNA polymerase cannot start a new strand; it can only add to a strand that has already been started. There are three main steps in PCR. These steps happen over and over in a cycle, as shown in the figure on the following page.

---

* ACADEMIC VOCABULARY

**segment** a portion, or a part
What is the purpose of PCR?

**THE PROCESS OF PCR**

1. **Separating** The container with all of the reactants is heated for a few seconds to separate the strands of DNA.

2. **Binding** The container is cooled and the primers bind to the DNA strands.

3. **Copying** The container is heated to the temperature at which the polymerases work best. The polymerases add nucleotides until the DNA segment has been copied.

---

**Vocabulary Check**

polymerase chain reaction (PCR)  
primer

1. What does a primer do? __________________________________________________________________________

2. What is the end result of PCR? ______________________________________________________________________

---

**The Big Picture**

3. The development of PCR was considered a major advance for genetics research. What can PCR do that is so important for genetics research? ______________________________________________________________________________________

4. What is the role of polymerase in PCR? ____________________________________________________________________________
A DNA fingerprint is a type of restriction map.

Except for identical twins, each person’s set of DNA, or genome, is unique. A DNA fingerprint shows parts of an individual’s DNA that can be used to identify a person. A DNA fingerprint is a type of restriction map, like the ones you read about in Section 9.1. A DNA sample is cut with a restriction enzyme, and the fragments are separated with gel electrophoresis. The pattern of bands that results is the DNA fingerprint.

The greatest differences in DNA are in certain areas of the genome called noncoding regions. These are parts of DNA that do not code for proteins and are not parts of genes. Noncoding regions often have areas in which a particular DNA sequence is repeated a number of times. One person might have seven repeats of the sequence and another person might have three repeats of the sequence. These differences can be seen when the two samples are cut with restriction enzymes and separated by gel electrophoresis.

**DNA Fingerprinting**

A DNA fingerprint shows differences in the number of repeats of certain DNA sequences.

This DNA sequence of 33 base pairs can be repeated many times in a sample of a person’s DNA.

Person A and person B have different numbers of repeated DNA sequences in their DNA.

A DNA fingerprint finds differences in DNA by separating the fragments on a gel.

DNA fragments with different numbers of repeated DNA sequences show up as different bands on a gel.

What is identified in DNA fingerprinting?
DNA fingerprinting is used for identification.

DNA fingerprinting has been widely used to identify people since the 1990s. All people have the same repeated DNA sequences. But the number of repeats differs greatly among people.

DNA fingerprinting uses more than one section of noncoding DNA. For example, five different regions of DNA might be used to make a DNA fingerprint. The more regions that are used, the less likely it is that two people will have the same DNA fingerprint. There is a very small chance—one in many millions—that two people have the same DNA fingerprint.

DNA fingerprinting is used for many different purposes.

- In legal cases, as evidence against a suspect or as evidence of a suspect’s innocence. DNA fingerprinting has helped free many people who were convicted of crimes they did not commit.
- To prove family relationships, such as paternity*, or to provide information necessary for immigration requests.
- To study biodiversity and to identify genetically engineered crops.

*ACADEMIC VOCABULARY

paternity the position of being a father

9.3 Vocabulary Check

DNA fingerprint

1. What is DNA fingerprinting?

2. What are two different uses of DNA fingerprinting?

3. What part of the human genome is used for DNA fingerprinting?
Entire organisms can be cloned.

A clone is a genetically identical copy of a gene or organism. Cloning is quite common in some organisms. For example, many plants can clone themselves from their roots. Bacteria make clones of themselves when they reproduce by dividing in two.

Mammals cannot clone themselves. But scientists have developed a technique to clone mammals in the laboratory. The nucleus of a cell from the animal to be cloned is put into an egg cell that has had its nucleus removed. If the procedure is successful, the egg will develop into a living copy of the original animal.

Although a clone is genetically identical to the original animal, it will likely look different and act different from the original. As you have learned, many factors, including environment, affect the expression of genes. A clone may also not be as healthy as the original animal, possibly because it has “old” DNA.

Cloning may be used for different purposes. For example, scientists are studying how to use organs from cloned mammals for transplant into humans.

What is one organism in which cloning is common?

New genes can be added to an organism’s DNA.

A copied gene is also called a clone. Scientists can insert a cloned gene from one organism into another organism. This process of changing an organism’s DNA to give the organism new traits is called genetic engineering. Genetic engineering uses recombinant DNA (ree-KAHM-buh-nuhnt), or DNA that contains genes from more than one organism. In many cases, foreign DNA is inserted into a plasmid to make recombinant DNA. Plasmids are closed loops of DNA in a bacterial cell.
Because the genetic code is shared by all organisms, a gene from one organism can be transcribed and translated in another organism.

**What is the term for a plasmid that contains a foreign gene?**

**Genetic engineering produces organisms with new traits.**

After a gene is added to a plasmid, the recombinant plasmid can be put into bacteria. The bacteria will express the new gene and make that gene’s product. The bacteria with the recombinant plasmid are called transgenic. A transgenic organism has one or more genes from another organism inserted into its genome. Transgenic bacteria with the gene for human insulin make human insulin that is used to treat people with diabetes.

**Genetic Engineering in Plants and Animals**

Scientists have made transgenic plants that have new traits, such as resistance to frost or disease. Some genetically engineered crops, also called genetically modified (GM) crops, are now common in the United States.

Scientists have made some transgenic animals, too. Transgenic mice are often used as models of human development and disease. One type of transgenic mouse is used to study cancer.
Another type of genetic manipulation involves “turning off” a particular gene in an organism. These organisms are called knockouts. For example, gene knockout mice have a gene that does not function because the gene has been deactivated. Knockouts help researchers to see what happens when a particular gene does not work. Knockout mice are used to study many different things, including genetic disorders and gene function.

**Concerns About Genetic Engineering**

There are some concerns about possible negative effects of genetically engineered organisms on human health and the environment. Some scientists think that too little research has been done on the possible side effects of eating GM foods over a long period of time. Scientists also have concerns about the effects of GM plants on the environment and on biodiversity.

What is one example of a transgenic organism?

**9.4 Vocabulary Check**

Choose the correct term from the list to complete each sentence.

1. An organism with recombinant DNA is called ____________________.
2. The purposeful disruption of the function of a particular gene in an organism is called a ____________________.
3. Genetic engineering makes use of a circular piece of bacterial DNA called a ____________________.

**9.4 The Big Picture**

4. Bacteria and humans are very different. But recombinant bacteria that have a human gene for insulin can produce human insulin. What characteristic of the genetic code makes it possible for bacteria to make a human protein? ____________________

5. Imagine that your friend’s cat was cloned. Would the clone be exactly like the original cat? Explain your answer. ____________________
Genomics involves the study of genes, gene functions, and entire genomes.

A gene is a segment of DNA. A genome is all of an organism’s DNA. And genomics is the study of genomes. Scientists compare genomes both within and across species. Comparing DNA from many organisms at one time can help scientists identify disease-causing genes, learn about evolutionary relationships, and discover how genes interact.

DNA Sequencing

Studies of genomics begin with gene sequencing. Gene sequencing means finding the order, or sequence, of nucleotides in genes or genomes. Gene sequences give scientists important clues about how genes function. Some organisms, such as fruit flies, yeast, and mice, are used as models for human gene functions and genetic disorders.

The Human Genome Project

In 1990 an international project to study the human genome began. The two main goals of the Human Genome Project are:

1. to map and sequence all of the DNA base pairs in the human chromosomes, and
2. to identify all of the genes within the sequence.

In 2003, scientists completed the first goal. They finished sequencing the human genome. But knowing the sequence of the billions of base pairs is just a beginning. Today, scientists continue to work to identify genes and figure out the functions of genes.

**Comparing Genome Sizes**

<table>
<thead>
<tr>
<th>Organism</th>
<th>Approximate Total DNA (millions of bases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. coli</td>
<td>4.6</td>
</tr>
<tr>
<td>Yeast</td>
<td>12.1</td>
</tr>
<tr>
<td>Fruit fly</td>
<td>165</td>
</tr>
<tr>
<td>Banana</td>
<td>873</td>
</tr>
<tr>
<td>Chicken</td>
<td>1200</td>
</tr>
<tr>
<td>Humans</td>
<td>3000</td>
</tr>
<tr>
<td>Vanilla</td>
<td>7672</td>
</tr>
<tr>
<td>Crested newt</td>
<td>18,600</td>
</tr>
<tr>
<td>Lungfish</td>
<td>139,000</td>
</tr>
</tbody>
</table>

Source: University of Nebraska

Different organisms have different sized genomes.

Underline the two main goals of the Human Genome Project.
Technology allows the study and comparison of both genes and proteins.

Some traits—like the ones Mendel studied with his pea plants—are controlled by a single gene. But most genes are not single units that work alone. Instead, most biological processes and physical traits are the result of the interactions among many genes. Technology is very important for organizing and analyzing large amounts of data about genes, genomes, and proteins.

**Bioinformatics**

Gene sequencing and other parts of genomic research produce huge amounts of data. These data are useful only if they are organized so that they can be analyzed. **Bioinformatics** is the use of computer databases to organize and analyze biological data. This has become a very important part of the study of genes and proteins. For example, a scientist can now search databases to find a gene that codes for a known protein.

**DNA Microarrays**

**DNA microarrays** are tools that allow scientists to study many genes, and their expression, at once. A microarray is a very small chip with thousands of genes laid out in a grid.

This chip can be used to scan tissue samples to identify which genes are expressed. The mRNA present in the tissue sample is converted into a complementary, single strand of DNA that is labeled with a fluorescent dye. This labeled DNA is added to the microarray and binds to its complementary DNA in the microarray. Wherever the labeled DNA binds to the DNA on the microarray, a glowing dot appears. The pattern of glowing dots on a microarray—those that are fluorescent—shows which genes are being expressed. This tool can be used in many ways. For example, the pattern of gene expression in healthy cells can be compared with the pattern of gene expression in cancer cells.

**Proteomics**

Genomics is the study of genomes. **Proteomics** (PROH-tee-AH-mihks) is the study of the proteins that result from an organism’s genome. Proteomics also includes the study of how proteins work and how they interact. The study of proteins can be very complicated. For example, a single gene can code for more than one protein, depending on how the mRNA is processed.
The study of proteins is very important for many areas of biology. For example, proteomics is important to the study of evolutionary histories and in the study of human disease. By better understanding the proteins that are involved in different diseases, such as cancer or heart disease, scientists might be able to develop new treatments that target the specific proteins.

What is the difference between proteomics and genomics?

Choose the correct term from the list for each description.

1. the use of computers to organize data
2. determining the order of nucleotides in DNA
3. the study of genomes
4. the study of proteins resulting from a genome
5. a tool used to study the expression of many genes at once

What are the two goals of the Human Genome Project?

Give one example of a technology that is used to study genes and genomes.

Go back and highlight each sentence that has a vocabulary word in bold.
Genetic screening can detect genetic disorders.

Genetic screening is the process of testing a sample of a person's DNA to determine that person’s risk of having a genetic disorder or passing on a genetic disorder. Genetic screening is not used to check for every possible genetic problem. But there are tests for many specific genetic disorders.

Identifying a genetic disease can help save lives by preparing a person with preventative treatment. It can also lead to some difficult choices. Suppose a person is at risk for passing on a genetic disease to his or her children. How should the person use that information? Should it influence the decision to have or not to have children? What would you do?

What is the purpose of genetic screening?

Gene therapy is the replacement of faulty* genes.

The goal of gene therapy is to treat a genetic disease by replacing a gene or adding a new gene into a person's genome. But how can a gene be inserted into a person's genome? One method that scientists have tried is to get the gene into stem cells in the patient’s bone marrow. Because stem cells continue to divide, they will continue to express the inserted gene.

Gene therapy has had some successes, but much of gene therapy is still experimental. For example, scientists are working to insert a gene into a person's genome that will make the person's immune system attack cancer cells. Although gene therapy is still experimental, research in this field continues because it has great potential for treating disease.

What is the purpose of gene therapy?

* ACADEMIC VOCABULARY

faulty having error
Choose the correct term from the list for each description.

1. the replacement of a defective or missing gene, or the addition of a new gene into a person's genome ____________________________

2. the process of testing DNA to determine a person's risk of having or passing on a genetic disorder ____________________________

3. Which would come first, genetic screening or gene therapy? Explain. ____________________________________________________
   ____________________________________________________
Chapter 9 Review

1. What is the name of the substance that is used to cut DNA at particular sequences?

2. The drawing below shows the result of gel electrophoresis. Circle the band that represents the largest fragment of DNA.

3. How do the DNA base pairing rules apply to PCR?

4. Which of the following can be used to identify a person?
   a. a gene
   b. proteomics
   c. a DNA fingerprint
   d. a restriction enzyme

5. What is the name of the item shown in the drawing below?

6. Which of the following is a true statement about clones?
   a. they look identical
   b. they have identical DNA
   c. there are no differences between clones
   d. no clones exist in nature

7. How are restriction enzymes used to make recombinant DNA? B.7.5

8. What is the Human Genome Project? NOS.10