SECTION 1

What Does DNA Look Like?

For many years, the structure of a DNA molecule was a puzzle to scientists. In the 1950s, two scientists deduced the structure while experimenting with chemical models. They later won a Nobel Prize for helping solve this puzzle!

Inherited characteristics are determined by genes, and genes are passed from one generation to the next. Genes are parts of chromosomes, which are structures in the nucleus of most cells. Chromosomes are made of protein and DNA. **DNA** stands for *deoxyribonucleic acid* (dee AHKS ee RIE boh noo KLEE ik AS id). DNA is the genetic material—the material that determines inherited characteristics. But what does DNA look like?

READING WARM-UP

Objectives

- List three important events that led to understanding the structure of DNA.
- Describe the basic structure of a DNA molecule.
- Explain how DNA molecules can be copied.

Terms to Learn

DNA
nucleotide

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

The Pieces of the Puzzle

Scientists knew that the material that makes up genes must be able to do two things. First, it must be able to give instructions for building and maintaining cells. Second, it must be able to be copied each time a cell divides, so that each cell contains identical genes. Scientists thought that these things could be done only by complex molecules, such as proteins. They were surprised to learn how much the DNA molecule could do.

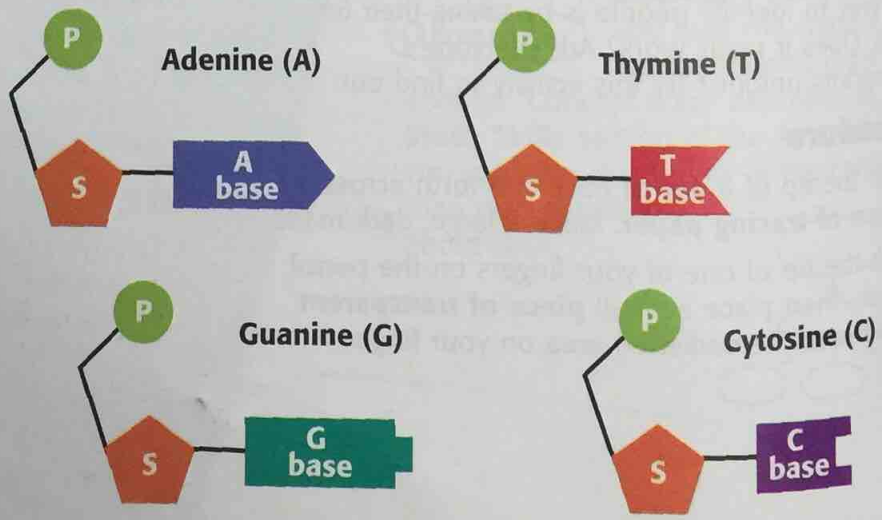
Nucleotides: The Subunits of DNA

DNA is made of subunits called nucleotides. A **nucleotide** consists of a sugar, a phosphate, and a base. The nucleotides are identical except for the base. The four bases are *adenine*, *thymine*, *guanine*, and *cytosine*. Each base has a different shape. Scientists often refer to a base by the first letter of the base, *A*, *T*, *G*, and *C*. **Figure 1** shows models of the four nucleotides.

DNA deoxyribonucleic acid, a molecule that is present in all living cells and that contains the information that determines the traits that a living thing inherits and needs to live

nucleotide in a nucleic-acid chain, a subunit that consists of a sugar, a phosphate, and a nitrogenous base

Figure 1 The Four Nucleotides of DNA



Chargaff's Rules

In the 1950s, a biochemist named Erwin Chargaff found that the amount of adenine in DNA always equals the amount of thymine. And he found that the amount of guanine always equals the amount of cytosine. His findings are known as *Chargaff's rules*. At the time of his discovery, no one knew the importance of these findings. But Chargaff's rules later helped scientists understand the structure of DNA.

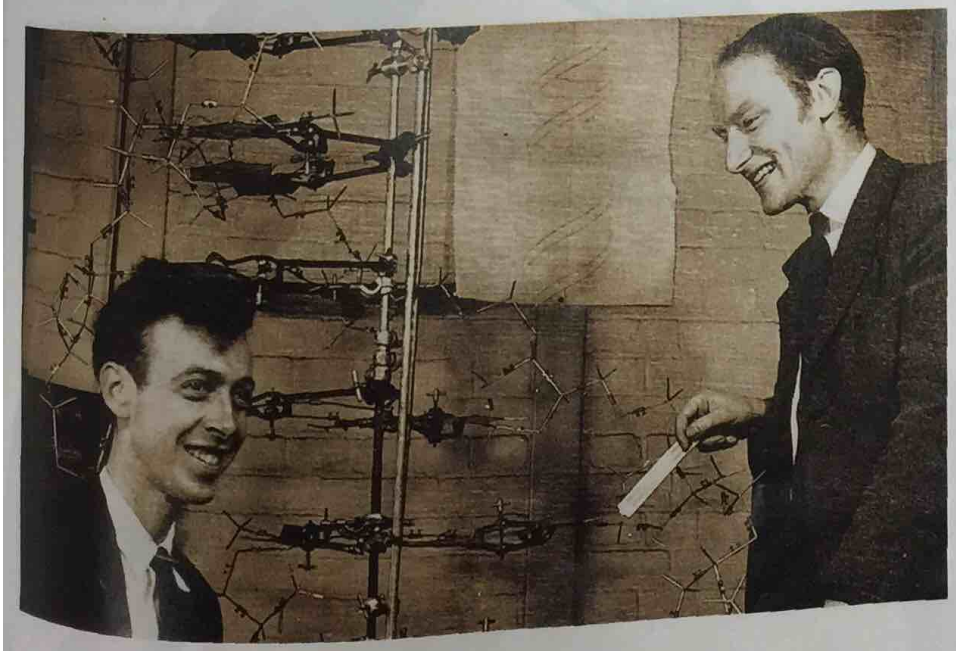
Reading Check **Summarize Chargaff's rules.** (*See the Appendix for answers to Reading Checks.*)

Franklin's Discovery

More clues about the structure of DNA came from scientists in Britain. There, chemist Rosalind Franklin, shown in **Figure 2,** was able to make images of DNA molecules. She used a process known as *X-ray diffraction* to make these images. In this process, X rays are aimed at the DNA molecule. When an X ray hits a part of the molecule, the ray bounces off. The pattern made by the bouncing rays is captured on film. Franklin's images suggested that DNA has a spiral shape.

Watson and Crick's Model

At about the same time, two other scientists were also trying to solve the mystery of DNA's structure. They were James Watson and Francis Crick, shown in **Figure 3.** After seeing Franklin's X-ray images, Watson and Crick concluded that DNA must look like a long, twisted ladder. They were then able to build a model of DNA by using simple materials from their laboratory. Their model perfectly fit with both Chargaff's and Franklin's findings. The model eventually helped explain how DNA is copied and how it functions in the cell.



CONNECTION TO Chemistry

WRITING SKILL **Linus Pauling** Many scientists contributed to the discovery of DNA's structure. In fact, some scientists competed to be the first to make the discovery. One of these competitors was a chemist named Linus Pauling. Research and write a paragraph about how Pauling's work helped Watson and Crick.

Figure 2 *Rosalind Franklin used X-ray diffraction to make images of DNA that helped reveal the structure of DNA.*

Figure 3 *This photo shows James Watson (left) and Francis Crick (right) with their model of DNA.*

DNA's Double Structure

The shape of DNA is shown in **Figure 4.** As you can see, a strand of DNA looks like a twisted ladder. This shape is known as a *double helix* (DUB uhl HEE LIKS). The two sides of the ladder are made of alternating sugar parts and phosphate parts. The rungs of the ladder are made of a pair of bases. Adenine on one side of a rung always pairs with thymine on the other side. Guanine always pairs with cytosine.

Notice how the double helix structure matches Chargaff's observations. When Chargaff separated the parts of a sample of DNA, he found that the matching bases were always present in equal amounts. To model how the bases pair, Watson and Crick tried to match Chargaff's observations. They also used information from chemists about the size and shape of each of the nucleotides. As it turned out, the width of the DNA ladder matches the combined width of the matching bases. Only the correct pairs of bases fit within the ladder's width.

Making Copies of DNA

The pairing of bases allows the cell to *replicate*, or make copies of, DNA. Each base always bonds with only one other base. Thus, pairs of bases are *complementary* to each other, and both sides of a DNA molecule are complementary. For example, the sequence CGAC will bond to the sequence GCTG.

QUICK LAB

Making a Model of DNA

1. Gather assorted simple materials that you could use to build a basic model of DNA. You might use **clay, string, toothpicks, paper, tape, plastic foam,** or **pieces of food.**
2. Work with a partner or a small team to build your model. Use your book and other resources to check the details of your model.
3. Show your model to your classmates. Give your classmates feedback about the scientific aspects of their models.

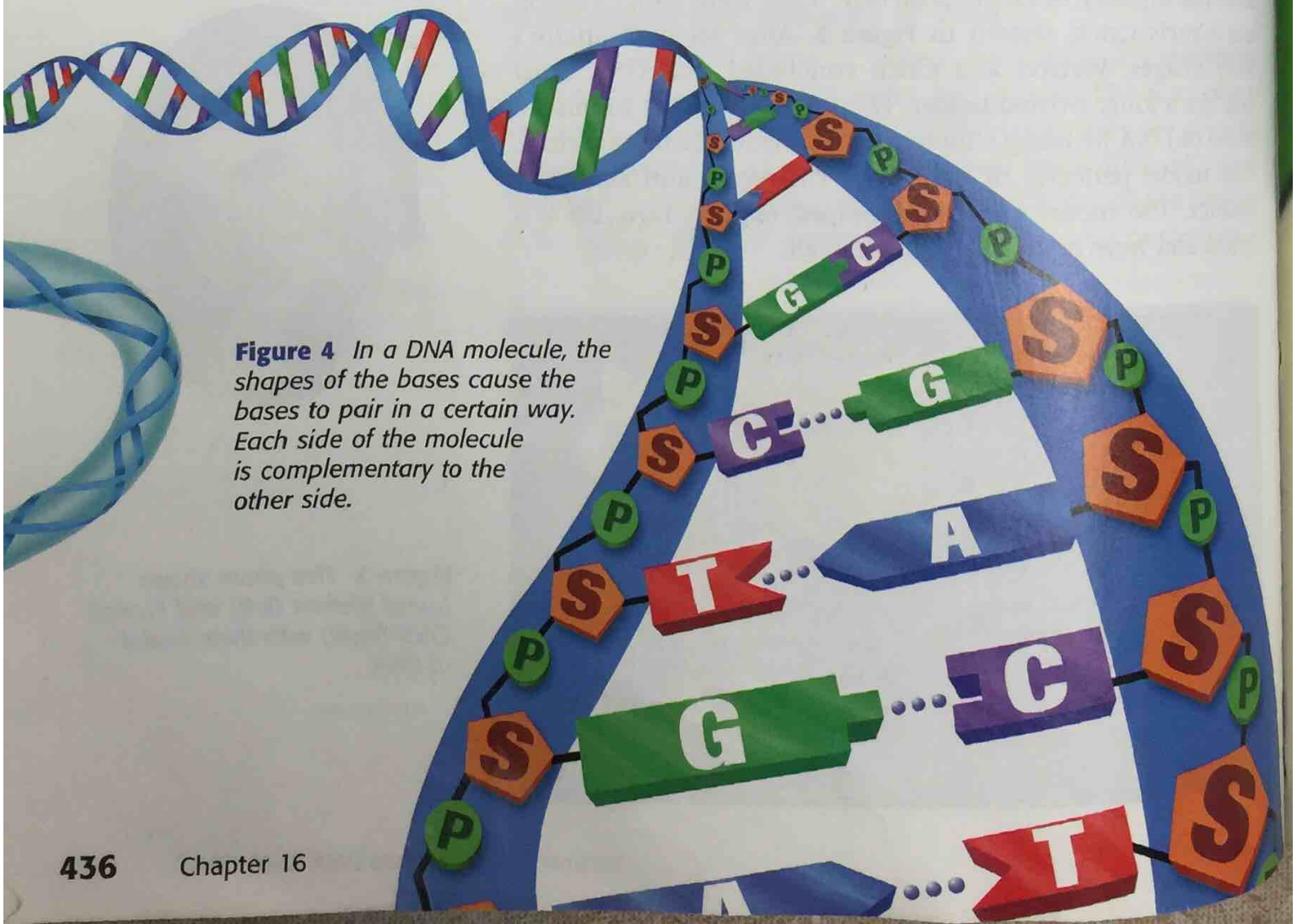


Figure 4 *In a DNA molecule, the shapes of the bases cause the bases to pair in a certain way. Each side of the molecule is complementary to the other side.*

How Copies Are Made

During replication, as shown in **Figure 5**, a DNA molecule is split down the middle, where the bases meet. The bases on each side of the molecule are used as a pattern for a new strand. As the bases on the original molecule are exposed, complementary nucleotides are added to each side of the ladder. Two DNA molecules are formed. Half of each of the molecules is old DNA, and half is new DNA.

When Copies Are Made

DNA is copied every time a cell divides. Each new cell gets a complete copy of all the DNA. The job of unwinding, copying, and re-winding the DNA is done by proteins within the cell. So, DNA is usually found with several kinds of proteins. Other proteins help with the process of carrying out the instructions written in the code of the DNA.

Reading Check How often is DNA copied?

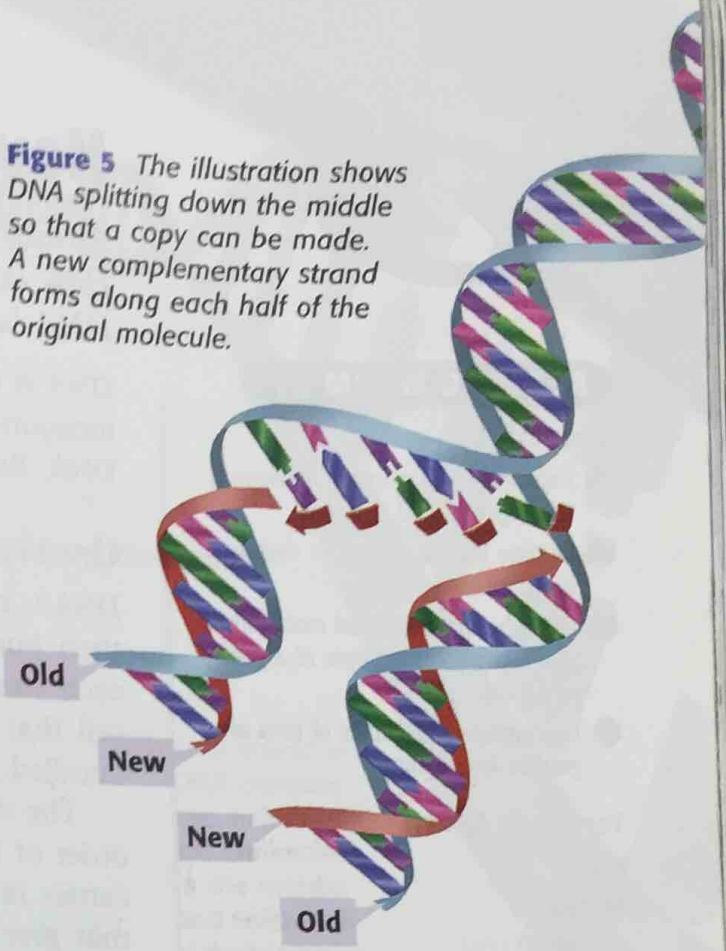


Figure 5 *The illustration shows DNA splitting down the middle so that a copy can be made. A new complementary strand forms along each half of the original molecule.*

SECTION Review

Summary

- DNA is the material that makes up genes. It carries coded information that is copied in each new cell.
- The DNA molecule looks like a twisted ladder. The two halves are long strings of nucleotides. The rungs are complementary pairs of bases.
- Because each base has a complementary base, DNA can be replicated accurately.

Using Key Terms

1. Use the term *DNA* in a sentence.
2. In your own words, write a definition for the term *nucleotide*.

Understanding Key Ideas

3. List three important events that led to understanding the structure of DNA.
4. Which of the following is NOT part of a nucleotide?
   - **a.** base
   - **b.** sugar
   - **c.** fat
   - **d.** phosphate

Math Skills

5. If a sample of DNA contained 20% cytosine, what percentage of guanine would be in this sample? What percentage of adenine would be in the sample? Explain.

Critical Thinking

6. **Making Inferences** Explain what is meant by the statement "DNA unites all organisms."
7. **Applying Concepts** What would the complementary strand of DNA be for the sequence of bases below?

   C T T A G G C T T A C C A

8. **Analyzing Processes** How are copies of DNA made? Draw a picture as part of your answer.

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