

Identifying the Genetic Material

Objectives

- **Relate** Griffith's conclusions to the observations he made during the transformation experiments. ★ 2C 3F TAKS 1
- **Summarize** the steps involved in Avery's transformation experiments, and state the results. ★ 3F
- **Evaluate** the results of the Hershey and Chase experiment. ★ 3F

Key Terms

vaccine
virulent
transformation
bacteriophage

Transformation

Mendel's experiments and results answered the question of why you resemble your parents. You resemble your parents because you have copies of their chromosomes, which contain sets of instructions called genes. But Mendel's work created more questions, such as, What are genes made of? Scientists believed that if they could answer this question they would understand how chromosomes function in heredity. 1

Griffith's Experiments

In 1928, an experiment completely unrelated to the field of genetics led to an astounding discovery about DNA. Frederick Griffith, a bacteriologist, was trying to prepare a vaccine (*vahk SEEN*) against pneumonia. *Streptococcus pneumoniae* (abbreviated *S. pneumoniae*), is shown in **Figure 1**. *S. pneumoniae* is a prokaryote (of the type commonly called a bacterium) that causes pneumonia. A **vaccine** is a substance that is prepared from killed or weakened disease-causing agents, including certain bacteria. The vaccine is introduced into the body to protect the body against future infections by the disease-causing agent. 2

Griffith worked with two types, or strains, of *S. pneumoniae*, as shown in **Figure 2**. The first strain is enclosed in a capsule composed of polysaccharides. The capsule protects the bacterium from the body's defense systems. This helps make the microorganism **virulent** (*VIHR yoo luhnt*), or able to cause disease. Because of the capsule, this strain of *S. pneumoniae* grows as smooth-edged (S) colonies when grown in a Petri dish. The second strain of *S. pneumoniae* lacks the polysaccharide capsule and does not cause disease. When grown in a Petri dish, the second strain forms rough-edged (R) colonies. 2

Griffith knew that mice infected with the S bacteria grew sick and died, while mice infected with the R bacteria were not harmed, as shown in **Figure 2**. To determine whether the capsule on the S bacteria was causing the mice to die, Griffith injected the mice with dead S bacteria. The mice remained healthy. Griffith then prepared a vaccine of weakened S bacteria by raising their temperature to a point at which the bacteria were "heat-killed," meaning that they could no longer reproduce. (The capsule remained on the bacteria). 2

Figure 1 *Streptococcus pneumoniae*

Certain types of *S. pneumoniae* bacteria can cause the lung disease pneumonia.

Magnification: 17,250×

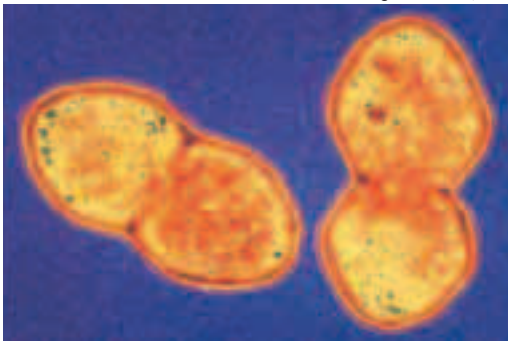
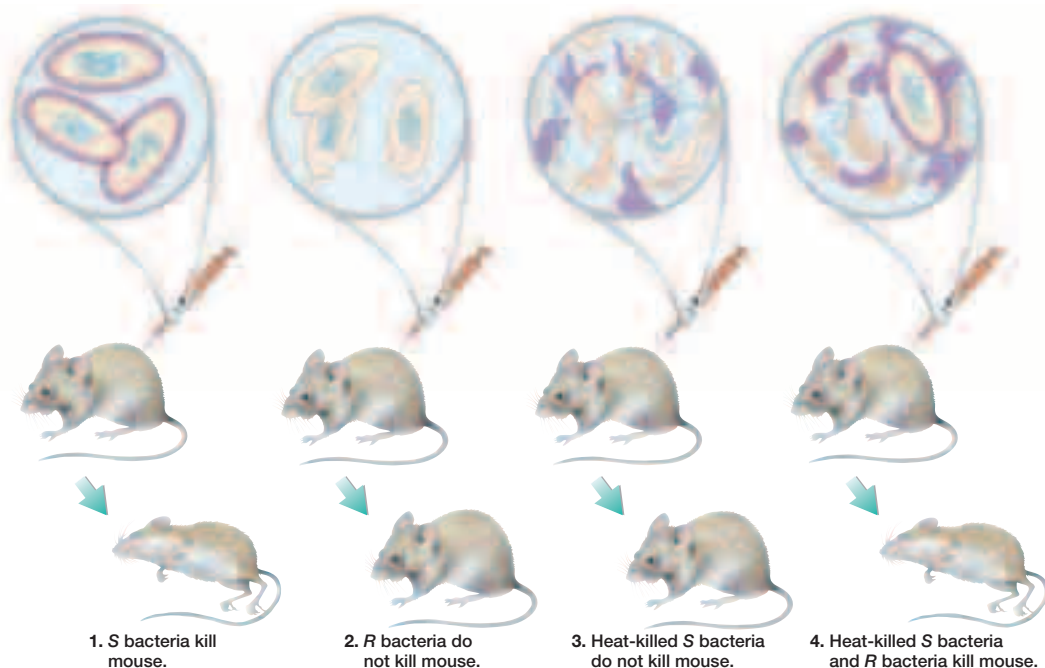


Figure 2 Griffith's discovery of transformation

Griffith discovered that harmless bacteria could turn virulent when mixed with bacteria that cause disease.



When Griffith injected mice with heat-killed *S* bacteria, the mice still lived. Thus, Griffith knew it was not the capsule on the *S* bacteria that killed the mice. He then mixed the harmless live *R* bacteria with the harmless heat-killed *S* bacteria. Mice injected with this mixture of previously harmless preparations died. When Griffith examined the blood of the dead mice, he found that the live *R* bacteria had acquired capsules. Somehow, the harmless *R* bacteria had changed and became virulent *S* bacteria. Griffith had discovered what is now called transformation. **Transformation** is a change in genotype caused when cells take up foreign genetic material. But the cause of the transformation was not known at the time. 1

Avery's Experiments

The search for the substance responsible for transformation continued until 1944. Then, an elegant series of experiments showed that the activity of the material responsible for transformation is not affected by protein-destroying enzymes. The activity is stopped, however, by a DNA-destroying enzyme. Thus, almost 100 years after Mendel's experiments, Oswald Avery and his co-workers at the Rockefeller Institute, in New York City, demonstrated that DNA is the material responsible for transformation. DNA contains the instructions for the making of the capsule in the *S* strain of *S. pneumoniae*.

WORD Origins

The word *virulent* is from the Latin *virulentus*, which means "full of poison." Knowing this makes it easier to remember that a microorganism's virulence is its ability to cause disease.

Viral Genes and DNA

Even though Avery's experiments clearly indicated that the genetic material is composed of DNA, many scientists remained skeptical. Scientists knew that proteins were important to many aspects of cell structure and metabolism, so most of them suspected that proteins were the genetic material. They also knew very little about DNA, so they could not imagine how DNA could carry genetic information.

Figure 3

BIO
graphic

The Hershey-Chase Experiment

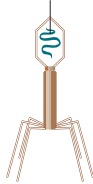
Bacteriophages were used to show that DNA, not protein, is the genetic material of viruses.

1 T2 phages were labeled with radioactive isotopes.

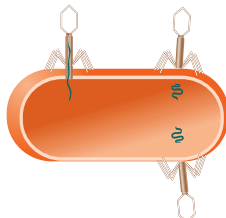
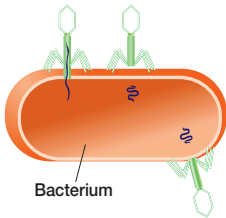
Virus's protein coat
labeled with ^{35}S



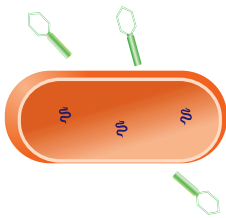
Virus's DNA core
labeled with ^{32}P



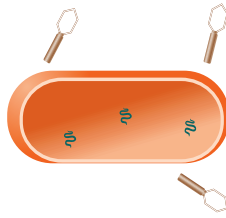
2 The phages infect *E. coli* bacterial cells.



3 Bacterial cells were spun to remove the virus's protein coats.



^{35}S radioactivity
remained in phages.



^{32}P radioactivity
moved into cells.

DNA's Role Revealed

In 1952, Alfred Hershey and Martha Chase, scientists at Cold Spring Harbor Laboratory, in New York, performed an experiment that settled the controversy. It was known at that time that viruses, which are much simpler than cells, are composed of DNA or RNA surrounded by a protective protein coat. A **bacteriophage** (*bak TIHR ee uh fayj*), also referred to as phage (*fayj*), is a virus that infects bacteria. It was also known that when phages infect bacterial cells, the phages are able to produce more viruses, which are released when the bacterial cells rupture. 1

What was not known at the time was how the bacteriophage reprograms the bacterial cell to make viruses. Does the phage DNA, the protein, or both issue instructions to the bacteria?

Hershey and Chase used the bacteriophage T2, shown in Figure 3, to answer this question. Hershey and Chase knew that the only molecule in the phage that contains phosphorus is its DNA. Likewise, the only phage molecules that contain sulfur are the proteins in its coat. Hershey and Chase used these differences to carry out the experiment shown in Figure 3.

Step 1 Hershey and Chase first grew T2 with *Escherichia coli* (abbreviated *E. coli*) bacteria in a nutrient medium that contained radioactive sulfur (^{35}S). The protein coat of the virus would incorporate the ^{35}S . They grew a second batch of phages with *E. coli* bacteria in a nutrient medium that contained radioactive phosphorus (^{32}P). The radioactive phosphorus would become part of the phages' DNA.

Step 2 The ^{35}S -labeled and ^{32}P -labeled phages were used to infect two separate batches of *E. coli* bacteria. Because radioactive elements release particles that can be detected with machines, they can be followed, or traced, in a biological process. Scientists could determine whether it was the DNA, the protein, or both that were being transferred into the bacterial cells to reprogram the bacteria.

Step 3 After a few minutes, the scientists tore the ^{35}S -labeled phages off the surfaces of the bacteria (with the help of a blender). The bacteria infected with the ^{32}P -labeled phage were likewise mixed in a blender. The investigators used a centrifuge to separate the bacteria and phages. The heavier, bacterial cells formed a solid layer at the bottom of the centrifuge tubes. The lighter, viral parts remained in the upper, liquid layer.

Hershey and Chase examined the layers from the ^{35}S -infected bacteria. The scientists found that most of the ^{35}S label was still part of the phage (the upper layer), meaning the protein was not injected into the bacteria. When they examined the layers from the ^{32}P -infected bacteria, the scientists found that the ^{32}P label mostly in the layer containing the bacterial cells (the lower layer). The DNA had been injected into the hosts. Moreover, the new generation of phages that was produced by these bacteria also contained radioactive DNA.

Hershey and Chase concluded that the DNA of viruses is injected into the bacterial cells, while most of the viral proteins remain outside. The injected DNA molecules causes the bacterial cells to produce more viral DNA and proteins. This meant that the DNA, rather than proteins, is the hereditary material, at least in viruses. **1**

These important experiments, and many others since, have shown that DNA is the molecule that stores genetic information in living cells. As you will see in the next section, the structure of DNA makes DNA particularly well suited to this function.

Real Life

Many viruses infect humans.

Although the T2 viruses used by Hershey and Chase infect bacteria, many other viruses infect humans. For example, viruses are responsible for causing polio, the common cold, measles, and rabies.

Finding Information

Research other human diseases that are caused by viruses.

TAKS 3



Section 1 Review

1 Summarize Griffith's transformation experiments. ★ 3F

2 Describe how Avery's experiment supplied evidence that DNA, and not protein, is the genetic material. ★ 3F

3 Describe the contributions of Hershey and Chase to the understanding that DNA is the genetic material. ★ 3F

4 Critical Thinking Evaluating Methods Why did heat kill Griffith's *S* bacteria? ★ 2C 3F

5 Critical Thinking Applying Information What might Hershey and Chase have concluded if they had found ^{32}P and ^{35}S in the bacterial cells? ★ 3A

6 TAKS Test Prep The first experiments that correctly identified the molecule that carries genetic information were performed by ★ 3F

A Oswald Avery

C Frederick Griffith

B Alfred Hershey

D Martha Chase

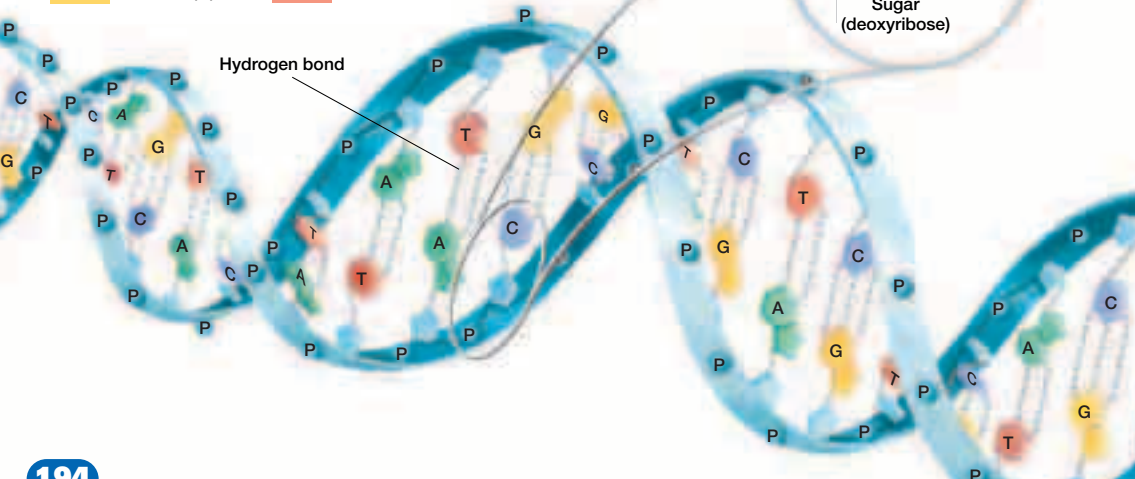
Objectives

- **Describe** the three components of a nucleotide. ★ 6A TAKS 2
- **Develop** a model of the structure of a DNA molecule. ★ 6A TAKS 2
- **Evaluate** the contributions of Chargaff, Franklin, and Wilkins in helping Watson and Crick determine the double-helical structure of DNA. ★ 3F
- **Relate** the role of the base-pairing rules to the structure of DNA. ★ 6A TAKS 2

Key Terms

double helix
nucleotide
deoxyribose
base-pairing rules
complementary base pair

	Adenine (A)		Cytosine (C)
	Guanine (G)		Thymine (T)



A Winding Staircase

By the early 1950s, most scientists were convinced that genes were made of DNA. They hoped that the mystery of heredity could be solved by understanding the structure of DNA. The research of many scientists led two young researchers at Cambridge University, James Watson and Francis Crick, to piece together a model of the structure of DNA. The discovery of DNA's structure was important because it clarified *how* DNA could serve as the genetic material.

Watson and Crick determined that a DNA molecule is a **double helix**—two strands twisted around each other, like a winding staircase. As shown in **Figure 4**, each strand is made of linked nucleotides (*NOO klee oh tiedz*). **Nucleotides** are the subunits that make up DNA. Each nucleotide is made of three parts: a phosphate group, a five-carbon sugar molecule, and a nitrogen-containing base. Figure 4 shows how these three parts are arranged to form a nucleotide. The five-carbon sugar in DNA nucleotides is called **deoxyribose** (*dee ahk see RIE boh*s), from which DNA gets its full name, deoxyribonucleic acid. **1**

Figure 4 DNA double helix

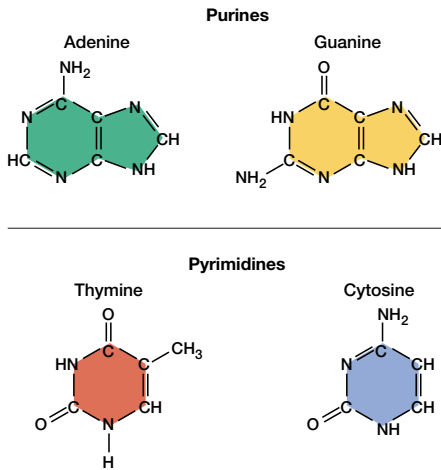
Watson and Crick's model of DNA is a double helix composed of two nucleotide chains that are twisted around a central axis and held together by hydrogen bonds.

While the sugar molecule and the phosphate group are the same for each nucleotide in a molecule of DNA, the nitrogen base may be any one of four different kinds. **Figure 5** illustrates the four different nitrogen bases in DNA: adenine (*AD uh neen*), guanine (*GWAH neen*), thymine (*THIE meen*), and cytosine (*SIET oh seen*). Adenine (A) and guanine (G) are classified as purines (*PYUR eenz*), nitrogen bases made of two rings of carbon and nitrogen atoms. Thymine (T) and cytosine (C) are classified as pyrimidines (*pih RIHM uh deenz*), nitrogen bases made of a single ring of carbon and nitrogen atoms. 1

Note how the DNA shown in Figure 4 resembles a ladder twisted like a spiral staircase. The sugar-phosphate backbones (the blue “ribbons”) are similar to the side rails of a ladder. The paired nitrogen bases are similar to the rungs of the ladder. The nitrogen bases face each other. The double helix is held together by weak hydrogen bonds between the pairs of bases. 1

Figure 5 Purines and pyrimidines

The nitrogen base in a nucleotide can be either a bulky, double-ring purine, or a smaller, single-ring pyrimidine.



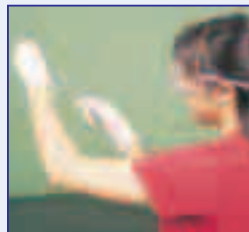
Observing Properties of DNA

★ 1A
TAKS 1

You can extract DNA from onion cells using ethanol and a stirring rod.

Materials

safety goggles and plastic gloves, 5 mL of onion extract, test tube, 5 mL of ice-cold ethanol, plastic pipet, glass stirring rod, test tube rack



QUICK LAB

Procedure

- Place 5 mL of onion extract in a test tube.
- CAUTION: Ethanol is flammable. Do not use it near a flame.**
Hold the test tube at a 45° angle. Use a pipet to add 5 mL of ice-cold ethanol to the tube one drop at a time.
NOTE: Allow the ethanol to run slowly down the side of the tube so that it forms a distinct layer.
- Let the test tube stand for 2–3 minutes.
- Insert a glass stirring rod into the boundary between the onion extract and ethanol. Gently twirl the stirring rod by rolling the handle between your thumb and finger.
- Remove the stirring rod from the liquids, and examine any material that has stuck to it. Touch the material to the lip of the test tube, and observe how the material acts as you try to remove it.
- Clean up your materials and wash your hands before leaving the lab.

Analysis

- Describe** any material that stuck to the stirring rod.
- Relate** the characteristics of your sample to the structural characteristics of DNA.
- Propose** a way to determine if the material on the stirring rod is DNA.

Discovering DNA's Structure

How were Watson and Crick able to determine the double helical structure of DNA? As with most discoveries in science, other scientists provided crucial pieces that helped them solve this puzzle.

Chargaff's Observations

In 1949, Erwin Chargaff, a biochemist working at Columbia University, in New York City, made an interesting observation about DNA. Chargaff's data showed that for each organism he studied, the amount of adenine always equaled the amount of thymine ($A=T$). Likewise, the amount of guanine always equaled the amount of cytosine ($G=C$). However, the amount of adenine and thymine and of guanine and cytosine varied between different organisms. **1**

Wilkins and Franklin's Photographs

The significance of Chargaff's data became clear in the 1950s when scientists began using X-ray diffraction to study the structures of molecules. In X-ray diffraction, a beam of X rays is directed at an object. The X rays bounce off the object and are scattered in a pattern onto a piece of film. By analyzing the complex patterns on the film, scientists can determine the structure of the molecule (much like shining a light on an object and then analyzing its shadow). **2**

In the winter of 1952, Maurice Wilkins and Rosalind Franklin, two scientists working at King's College in London, developed high-quality X-ray diffraction photographs of strands of DNA. These photographs, such as the one in **Figure 6**, suggested that the DNA molecule resembled a tightly coiled helix and was composed of two or three chains of nucleotides.



Figure 6 Franklin and her X-ray diffraction photo. The photographs revealed the X pattern characteristic of a helix. Franklin died of cancer when she was 37 years old.



Figure 7 Watson and Crick's model. The double-helical model of DNA takes into account Chargaff's observations and the patterns on Franklin's X-ray diffraction photographs.

Watson and Crick's DNA Model

The three-dimensional structure of the DNA molecule, however, was yet to be discovered. Any model had to take into account both Chargaff's findings and Franklin and Wilkins's X-ray diffraction data. In 1953, Watson and Crick used this information, along with their knowledge of chemical bonding, to come up with a solution. With tin-and-wire models of molecules, they built a model of DNA with the configuration of a double helix, a "spiral staircase" of two strands of nucleotides twisting around a central axis. **Figure 7** shows Watson (left) and Crick next to their tin-and-wire model of DNA. **1**

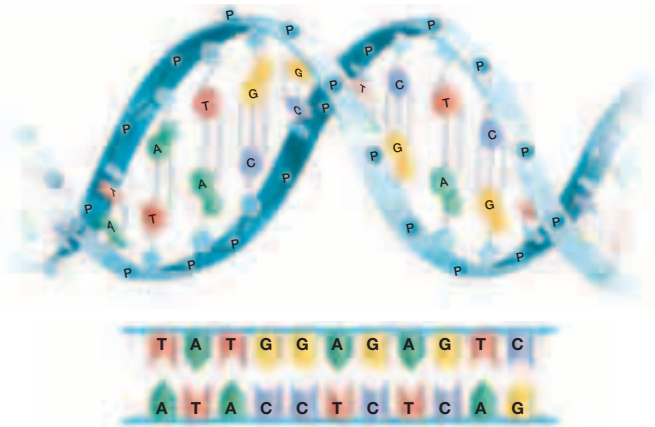


Figure 8 Base-pairing in DNA

The diagram of DNA below the helix makes it easier to visualize the base-pairing that occurs between DNA strands.

Pairing Between Bases

Watson and Crick determined that a purine on one strand of DNA is always paired with a pyrimidine on the opposite strand, as you can see in **Figure 8**. More specifically, an adenine on one strand always pairs with a thymine on the opposite strand, and a guanine on one strand always pairs with a cytosine on the opposite strand. The structure and size of the nitrogen bases allows for only these two paired combinations. These **base-pairing rules** are supported by Chargaff's observations. One easy way to visualize base-pairing is by simplifying the way in which DNA structure is represented, as shown in **Figure 8**.

Adenine forms two hydrogen bonds with thymine, and cytosine forms three hydrogen bonds with guanine. The hydrogen bonds between the nitrogen bases keep the two strands of DNA together. The strictness of base-pairing results in two strands that contain **complementary base pairs**. That is, the sequence of bases on one strand determines the sequence of bases on the other strand. For example, if the sequence of nitrogen bases on one strand of a DNA molecule is TCGAACT, the sequence of nitrogen bases on the other strand must be AGCTTGA. **1**

Study TIP

Organizing Information

Create a timeline that summarizes the people events that led to the discovery that DNA is the molecule where genetic information is stored. Start with 1928, and end with 1953.

Section 2 Review

- Describe** the three parts of a DNA nucleotide. ⭐ 6A
- Relate** the base-pairing rules to the structure of DNA. ⭐ 6A
- Describe** the two pieces of information from other scientists that enabled James Watson and Francis Crick to discover the double-helical structure of DNA. ⭐ 3F
- Explain** why the two strands of the double helix are described as complementary. ⭐ 6A
- Critical Thinking Applying Information**
Suppose a strand of DNA has the nucleotide sequence CCAGATTG. What is the nucleotide sequence of the complementary strand? ⭐ 6A
- TAKS Test Prep** Which pattern shows how bases pair in complementary strands of DNA? ⭐ 6A

A A-C and T-G	C A-G and T-C
B A-T and C-G	D A-A and C-C

Objectives

- **Summarize** the process of DNA replication. ⭐ 6B TAKS 2
- **Describe** how errors are corrected during DNA replication. ⭐ 6B 6C TAKS 2
- **Compare** the number of replication forks in prokaryotic and eukaryotic DNA. ⭐ 6B TAKS 2

Key Terms

DNA replication
DNA helicase
replication fork
DNA polymerase

Roles of Enzymes in DNA Replication

When the double helix structure of DNA was first discovered, scientists were very excited about the complementary relationship between the sequences of nucleotides. They predicted that the complementary structure was used as a basis to make exact copies of the DNA each time a cell divided. Watson and Crick proposed that one DNA strand serves as a template, or pattern, on which the other strand is built. Within five years of the discovery of DNA's structure, scientists had firm evidence that the complementary strands of the double helix do indeed serve as templates for building new DNA. 1

The process of making a copy of DNA is called **DNA replication**. DNA replication is summarized in **Figure 9**. Recall from your reading of earlier chapters that DNA replication occurs during the synthesis (S) phase of the cell cycle, before a cell divides. 1

Step 1 Before DNA replication can begin, the double helix unwinds. This is accomplished by enzymes called DNA helicases. **DNA helicases** open the double helix by breaking the hydrogen bonds that link the complementary nitrogen bases between the two strands.

Figure 9

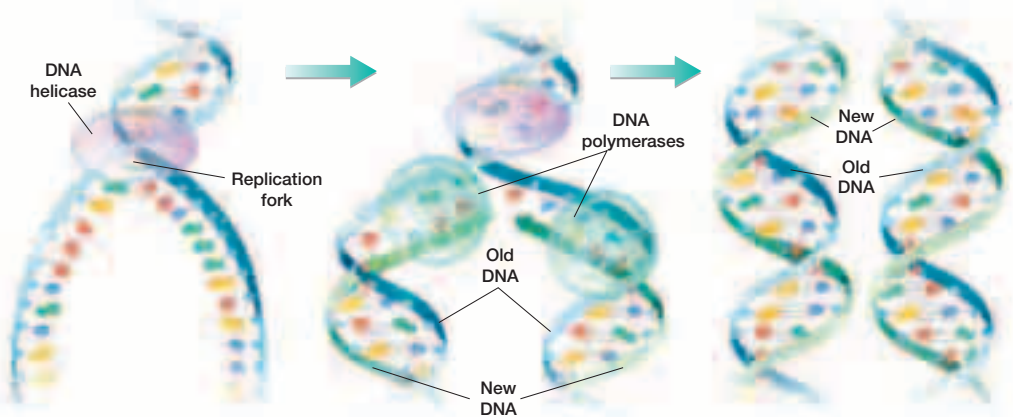
DNA Replication

DNA replication results in two identical DNA strands.

- 1 The two original DNA strands separate.

- 2 DNA polymerases add complementary nucleotides to each strand.

- 3 Two DNA molecules form that are identical to the original DNA molecule.



Once the two strands are separated, additional proteins attach to each strand, holding them apart and preventing them from assuming their double-helical shape. The areas where the double helix separates are called **replication forks** because of their Y shape, as shown in Figure 9.

Step 2 At the replication fork, enzymes known as **DNA polymerases** move along each of the DNA strands. DNA polymerases add nucleotides to the exposed nitrogen bases, according to the base-pairing rules. As the DNA polymerases move along, two new double helices are formed.

Step 3 Once DNA polymerases have begun adding nucleotides to a growing double helix, the process continues until all of the DNA has been copied and the polymerases are signaled to detach. This process produces two DNA molecules, each composed of a new and an original strand. The nucleotide sequences in both of these DNA molecules are identical to each other and to the original DNA molecule. **1**

Checking for Errors

In the course of DNA replication, errors sometimes occur and the wrong nucleotide is added to the new strand. An important feature of DNA replication is that DNA polymerases have a “proofreading” role. They can add nucleotides to a growing strand only if the previous nucleotide is correctly paired to its complementary base. In the event of a mismatched nucleotide, the DNA polymerase can backtrack. The DNA polymerase removes the incorrect nucleotide and replaces it with the correct one. This proofreading reduces errors in DNA replication to about one error per 1 billion nucleotides. **1**

Analyzing the Rate of DNA Replication

TAKS 1 Bio/IPC 2B, 2C;
TAKS 2 Bio 6B (grade 11 only)

Background

Cancer is a disease caused by cells that divide uncontrollably. Scientists studying drugs that prevent cancer often measure the effectiveness of a drug by its effect on DNA replication. During normal DNA replication, nucleotides are added at a rate of about 50 nucleotides per second in mammals and 500 nucleotides per second in bacteria.

Analysis

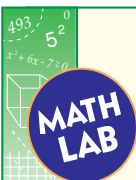
- 1. Calculate** the time it would take a bacterium to add 4,000 nucleotides to one DNA strand undergoing replication.
- 2. Calculate** the time it would take a mammalian cell to add 4,000 nucleotides to one DNA strand undergoing replication.
- 3. Critical Thinking Predicting Outcomes** How would the total time needed to add the 4,000 nucleotides be affected if a drug that inhibits DNA polymerases were present?

MATH TAKS Obj 9, 8.3B; Obj 10, 8.14A, C

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DNA replication forks



The Rate of Replication

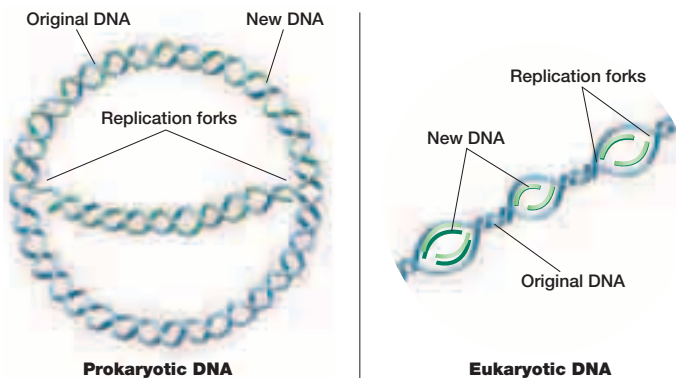


Replication does not begin at one end of the DNA molecule and end at the other. The circular DNA molecules found in prokaryotes usually have two replication forks that begin at a single point. The replication forks move away from each other until they meet on the opposite side of the DNA circle, as shown in **Figure 10. 1**

In eukaryotic cells, each chromosome contains a single, long strand of DNA. The length presents a challenge: The replication of a typical human chromosome with one pair of replication forks spreading from a single point, as occurs in prokaryotes, would take 33 days! To understand how eukaryotes meet this challenge, imagine that your class has to carry 25 boxes to another building. Carrying one box over, returning, carrying the second box, and so on, would be very slow. It would be much faster if everyone in the class picked up a box so that all of the boxes could be carried in one trip. That is similar to replication in eukaryotic cells, as shown in Figure 10. Each human chromosome is replicated in about 100 sections that are 100,000 nucleotides long, each section with its own starting point. With multiple replication forks working in concert, an entire human chromosome can be replicated in about 8 hours.

Figure 10 Replication forks

Prokaryotic and eukaryotic DNA have a different number of replication forks.



Section 3 Review

- 1 Explain** the two roles that enzymes play in DNA replication as is illustrated in Figure 9 in this section. ★ 6B
- 2 Explain** the relationship between DNA polymerases and mutations. ★ 6B 6C
- 3 State** the effect of multiple replication forks on the speed of replication in eukaryotes. ★ 6B

- 4 Critical Thinking Evaluating Information** If a mutation occurs during the formation of an egg cell or sperm cell, is that mutation more significant or less significant than a mutation that occurs in a body cell? Explain your answer. ★ 6C
- 5 ★ TAKS Test Prep** How many DNA strands exist after one molecule of DNA has been replicated? ★ 6B
A 1
B 2
C 4
D 8

1 Identifying the Genetic Material

- The experiments of Griffith and of Avery yielded results that suggested DNA was the genetic material.
- Hershey and Chase used the bacteriophage T2 and radioactive labels to show that viral genes are made of DNA, not protein.
- DNA stores the information that tells cells which proteins to make and when to make them.

2 The Structure of DNA

- DNA is made of two strands of nucleotides twisted into the form of a double helix.
- Each nucleotide in DNA is made of the sugar deoxyribose, a phosphate group, and one of four nitrogen bases. The four nitrogen bases found in DNA nucleotides are adenine (A), thymine (T), guanine (G), and cytosine (C).
- The two strands of DNA are complementary—each A on one strand pairs with a T on the opposite strand, and each G on one strand pairs with a C on the opposite strand.
- Watson and Crick determined the structure of DNA in 1952 with the help of data gathered by Wilkins, Franklin, and Chargaff.

3 The Replication of DNA

- Before a cell divides, it copies its DNA by a process called DNA replication.
- In DNA replication, enzymes work to unwind and separate the double helix and add complementary nucleotides to the exposed strands.
- The result of DNA replication is two exact copies of the cell's original DNA. Each new double helix is composed of one original DNA strand and one new DNA strand.
- DNA polymerase proofreads DNA during its replication so that very few errors occur.

Section 1

vaccine (190)
virulent (190)
transformation (191)
bacteriophage (192)

Section 2

double helix (194)
nucleotide (194)
deoxyribose (194)
base-pairing rules (197)
complementary base pair (197)

Section 3

DNA replication (198)
DNA helicase (198)
replication fork (199)
DNA polymerase (199)

Using Key Terms

1. What is the name of the process that was involved in changing Griffith's *R* bacteria to *S* bacteria? 3F 4D
 - a. DNA replication
 - b. polymerization
 - c. transformation
 - d. crossing-over
 2. The enzymes that add complementary nucleotides during DNA replication and proofread the new DNA strand are called 6A 6B
 - a. DNA polymerases.
 - b. phages.
 - c. DNA helicases.
 - d. nitrogen bases.
 3. Hershey and Chase showed that the genetic material of the T2 bacteriophage was 3F 4C
 - a. protein.
 - b. DNA.
 - c. DNA helicase.
 - d. DNA polymerase.
 4. A _____ is *not* a component of a DNA nucleotide. 6A
 - a. five-carbon sugar
 - b. phosphate group
 - c. double helix
 - d. nitrogen base
 5. Write a sentence that shows your understanding of the following terms: *DNA helicase*, *replication fork*, and *DNA polymerase*.
9. If the sequence of nucleotides on one strand of a DNA molecule is GCCATTG, the sequence on the complementary strand is 6A
 - a. GGGTAAG.
 - b. CCCTAAC.
 - c. CCGTAAC.
 - d. GCCATTC.
 10. Multiple replication forks along the DNA 6A
 - a. correct replication errors.
 - b. reduce DNA replication time.
 - c. ensure that the new and old DNA strands are complementary.
 - d. signal DNA polymerase to stop.
 11. The table below summarizes the percentage of each nitrogen base found in an organism's DNA. 6A

Percentage of Each Nitrogen Base

	A	T	G	C
Human	30.4	30.1	19.6	19.9
Wheat	27.3	27.1	22.7	22.8
<i>E. coli</i>	24.7	23.6	26.0	25.7

- a. What is the ratio of purines to pyrimidines?
 - b. Within each organism, which nucleotides are found in similar percentages?
 - c. Do the ratio and percentages in (a) and (b) follow Chargaff's rule?
12. Does DNA replication occur immediately before asexual reproduction, before sexual reproduction, or before both? 6A 6B
 13. What are two functions of DNA polymerases during DNA replication?
 14. Differentiate between DNA, genes, chromatids, and chromosomes. (Hint: See Chapter 6, Section 1.) 6A

Understanding Key Ideas

6. In his experiments on *Streptococcus pneumoniae*, Griffith found that 3F 4D
 - a. the DNA of the heat-killed *S* bacteria entered some of the *R* bacteria.
 - b. the *S* bacteria were transformed.
 - c. the capsule did not protect the bacterium.
 - d. mice injected with the *R* bacteria died.
7. Hershey and Chase showed that 3F 4C
 - a. bacteriophages can infect human cells.
 - b. DNA controls heredity.
 - c. bacteria undergo transformation.
 - d. a vaccine for pneumonia could be produced.
8. James Watson and Francis Crick 3F
 - a. built a structural model of DNA.
 - b. discovered DNA replication.
 - c. used X-ray diffraction.
 - d. discovered DNA polymerases.
15. **Concept Mapping** Make a concept map that shows the structure of DNA and how it is copied. Try to include the following words in your concept map: *nucleotides*, *phosphate group*, *five-carbon sugar*, *nitrogen base*, *purine*, *pyrimidine*, *double helix*, *replication*, *DNA polymerases*, and *gene*.

Critical Thinking

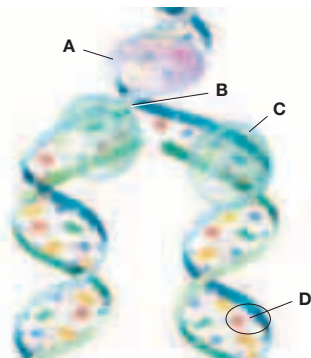
- 16. Forming Reasoned Opinions** X-rays damage DNA in organisms. Rosalind Franklin died of cancer at an early age. How might her work with X-ray diffraction have led to her death?
- 17. Evaluating Results** A scientist extracted 4.6 picograms (or 4.6×10^{-12} grams) of DNA from mouse muscle cells. How much DNA could be extracted from the same number of mouse kidney cells and the same number of mouse sperm? Explain your answer.
- 18. Evaluating Models** Explain why you do or do not think Watson and Crick's model of DNA illustrated in **Figure 7** in this chapter is a good representation of the structure of DNA. What existing information about DNA did Watson and Crick's model have to take into account? **3E**
- 19. Predicting Results** Identify the process by which new molecules of DNA are synthesized, and predict the effect on this process of reducing available DNA helicases. **2C 6A**

Alternative Assessment

- 20. Selecting Technology** Research two methods used to sequence the nucleotides in a gene. Compare and contrast the two methods. Give examples of how this technology might be used in a clinical setting. Prepare a poster to summarize the nucleotide-sequencing methods you researched.
- 21. Career Connection Molecular Biologist** Research the field of molecular biology, and write a report on your findings. Your report should include a job description, training required, kinds of employers, growth prospects, and starting salary. **3D**
- 21. Interactive Tutor Unit 6 Gene Expression** Write a report summarizing the use of polymerase chain reaction (PCR) in genetic engineering. Research how PCR analysis is applied in procedures such as DNA fingerprinting and genetic screening.

★ TAKS Test Prep

Use the model below and your knowledge of science to answer questions 1–3.



- 1.** Which part of the model represents DNA helicase? **6B**
- | | |
|------------|------------|
| A A | C C |
| B B | D D |

- 2.** Which cellular function does this model represent? **6A 6B**
- F** transformation
 - G** cellular respiration
 - H** photosynthesis
 - J** DNA replication
- 3.** What is the function of the structure labeled A?
- A** separating DNA strands
 - B** reconnecting DNA strands
 - C** adding nucleotides to make new DNA strands
 - D** checking the new DNA strands for errors

Test TIP

Some questions require you to choose the answer that is *not* true. For these questions, you should first eliminate answers that you know are true.