8.3 DNA Replication

KEY CONCEPT DNA replication copies the genetic information of a cell.

MAIN IDEAS

- Replication copies the genetic information.
- Proteins carry out the process of replication.
- Replication is fast and accurate.

VOCABULARY

replication, p. 235

DNA polymerase, p. 236

Review

base pairing rules, S phase

CALIFORNIA STANDARDS

5.b ***Students know*** **how to apply base-pairing rules to explain precise copying of DNA during semiconservative replication and transcription of information from DNA into mRNA.**

Connect Do you know that some of your cells are dying right now? You may live to the ripe old age of 100, but most of your cells will have been replaced thousands of times before you blow out the candles on that birthday cake. Every time that cells divide to produce new cells, DNA must first be copied in a remarkable process of unzipping and zipping by enzymes and other proteins. The next few pages will take you through that process.

MAIN IDEA

Replication copies the genetic information.

One of the powerful features of the Watson and Crick model was that it suggested a way that DNA could be copied. In fact, Watson and Crick ended the journal article announcing their discovery with this sentence: "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."

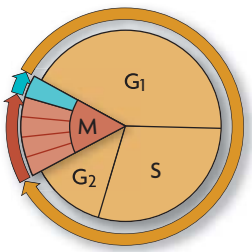
Recall that the bases that connect the strands of DNA will pair only in one way, according to the rules of base pairing. An A must bind with a T, and a C must bind with a G. If the base sequence of one strand of the DNA double helix is known, the sequence of the other strand is also known. Watson and Crick realized that a single DNA strand can serve as a template, or pattern, for a new strand. This process by which DNA is copied during the cell cycle is called **replication.**

Suppose all of your classmates took off their shoes, placed their left shoe in a line, and tossed their right shoe into a pile. You could easily pick out the right shoes from the pile and place them with the matching left shoes. The order of the shoes would be preserved. Similarly, a new strand of DNA can be synthesized when the other strand is a template to guide the process. Every time, the order of the bases is preserved, and DNA can be accurately replicated over and over again.

Replication assures that every cell has a complete set of identical genetic information. Recall that your DNA is divided into 46 chromosomes that are replicated during the S phase of the cell cycle. So your DNA is copied once in each round of the cell cycle. As a result, every cell has a complete set of DNA.

Connecting CONCEPTS

Cell Biology In **Chapter 5** you learned that the cell cycle has four main stages. DNA is replicated during the S (synthesis) stage.



The fact that cells throughout the body have complete sets of DNA is very useful for forensic scientists. They can identify someone from nearly any cell in the body. A few cells from a drop of blood or from saliva on a cigarette butt are all detectives need to produce a DNA "fingerprint" of a criminal suspect.

Apply **How does replication ensure that cells have complete sets of DNA?**

MAIN IDEA

Proteins carry out the process of replication.

Connecting CONCEPTS

Biochemistry You read in **Chapter 2** that many proteins are enzymes that function as catalysts. Enzymes decrease the activation energy and increase the rate of chemical reactions. DNA polymerase catalyzes the reaction that bonds two nucleotides together.

Although people may say that DNA copies itself, the DNA itself does nothing more than store information. Enzymes and other proteins do the actual work of replication. For example, some enzymes start the process by unzipping the double helix to separate the strands of DNA. Other proteins hold the strands apart while the strands serve as templates. Nucleotides that are floating free in the nucleus can then pair up with the nucleotides of the existing DNA strands. A group of enzymes called **DNA polymerases** (PAHL-uh-muh-rays) bond the new nucleotides together. When the process is finished, the result is two complete molecules of DNA, each exactly like the original double strand.

VISUAL VOCAB

DNA polymerases are enzymes that form bonds between nucleotides during replication.

The ending *-ase* signals that this is an enzyme.

DNA polymer**ase**

This part of the name tells what the enzyme does—makes DNA polymers.

The Replication Process

The following information describes the process of DNA replication in eukaryotes, which is similar in prokaryotes. As you read, follow along with each step illustrated in **FIGURE 8.8.**

1. Enzymes begin to unzip the double helix at numerous places along the chromosome, called origins of replication. That is, the hydrogen bonds connecting base pairs are broken, the original molecule separates, and the bases on each strand are exposed. Unlike unzipping a jacket, this process proceeds in two directions at the same time.
2. Free-floating nucleotides pair, one by one, with the bases on the template strands as they are exposed. DNA polymerases bond the nucleotides together to form new strands that are complementary to each template strand. DNA replication occurs in a smooth, continuous way on one of the strands. Due to the chemical nature of DNA polymerase, replication of the other strand is more complex. It involves the formation of many small DNA segments that are joined together. This more complex process is not shown or described in detail here.
3. Two identical molecules of DNA result. Each new molecule has one strand from the original molecule and one new strand. As a result, DNA replication is called semiconservative because one old strand is conserved, and one complementary new strand is made.

Infer **How does step 3 of replication show that DNA acts as a template?**

TAKING NOTES

Use a cycle diagram to take notes about processes such as replication.

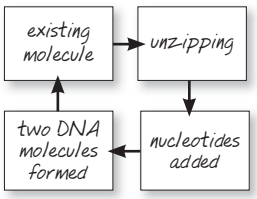
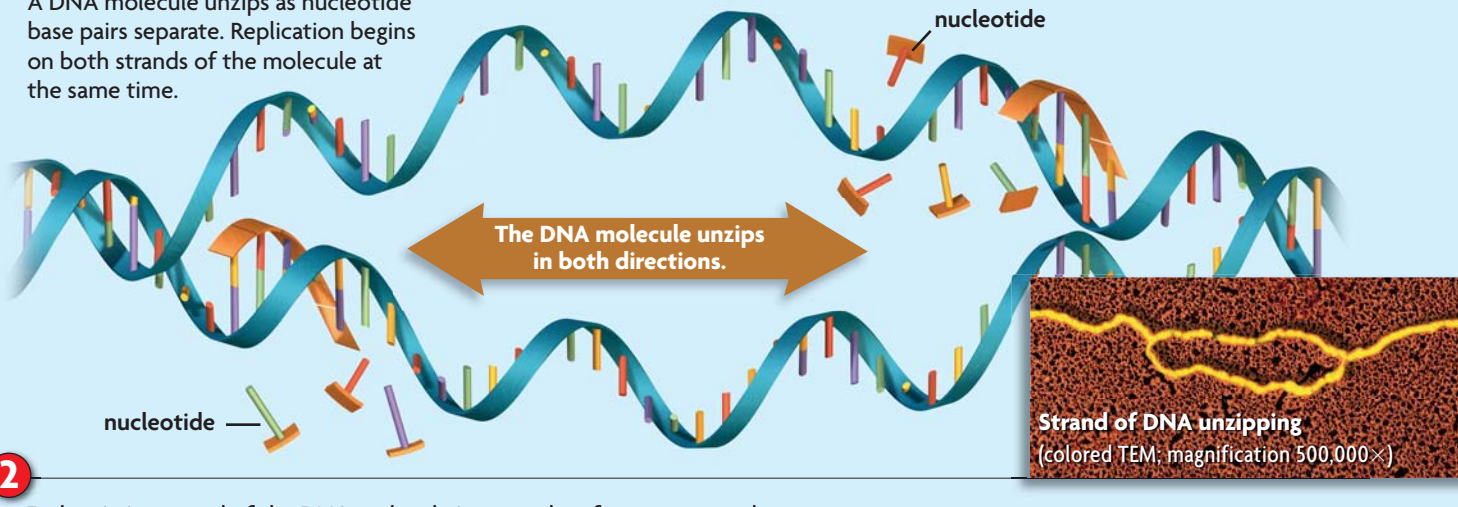


FIGURE 8.8 Replication

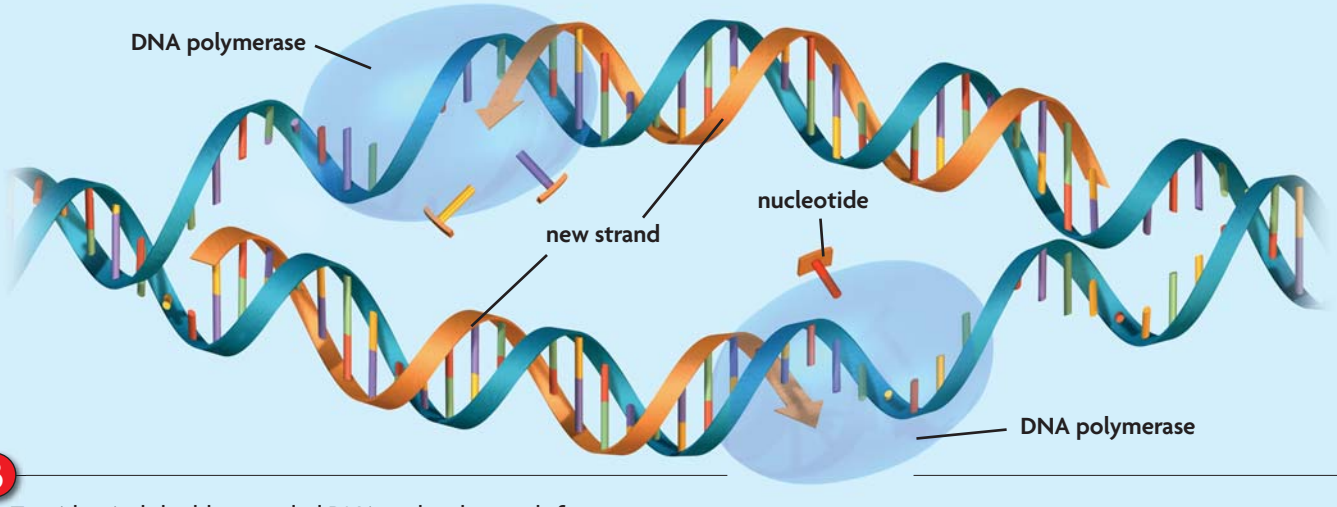
When a cell's DNA is copied, or replicated, two complete and identical sets of genetic information are produced. Then cell division can occur.

Animated BIOLOGY
See DNA replication in action at ClassZone.com.

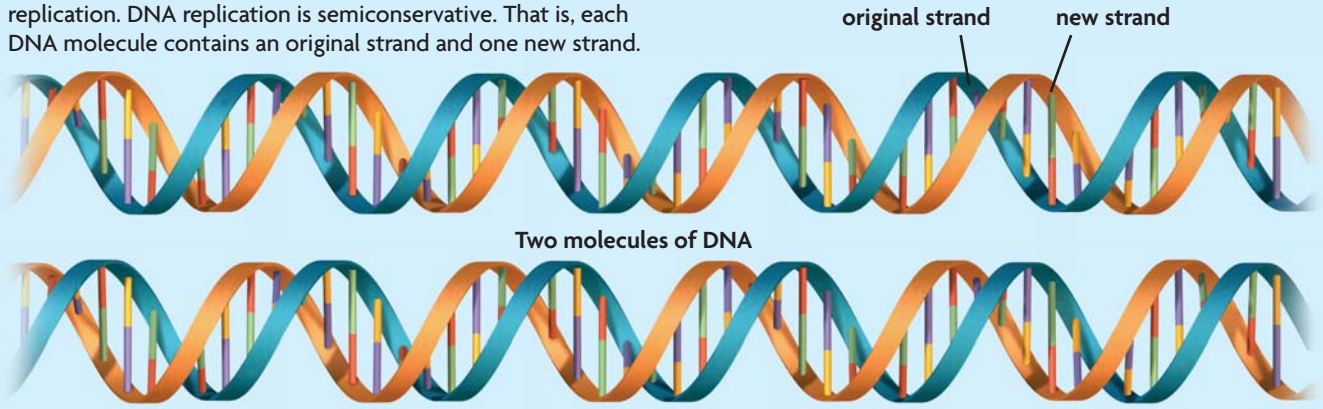
1 A DNA molecule unzips as nucleotide base pairs separate. Replication begins on both strands of the molecule at the same time.



2 Each existing strand of the DNA molecule is a template for a new strand. Free-floating nucleotides pair up with the exposed bases on each template strand. DNA polymerases bond these nucleotides together to form the new strands. The arrows show the directions in which new strands form.



3 Two identical double-stranded DNA molecules result from replication. DNA replication is semiconservative. That is, each DNA molecule contains an original strand and one new strand.



CRITICAL VIEWING **How is each new molecule of DNA related to the original molecule?**

CALIFORNIA STANDARDS

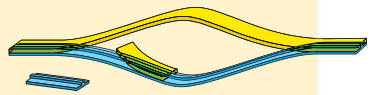
IE.1.g Recognize the usefulness and limitations of models and theories as scientific representations of reality.

QUICK LAB MODELING

Replication

Use two zipping plastic bags to model how complementary strands of DNA attach to template strands during replication.

MATERIALS
- 2 zipping bags
- scissors



PROCEDURE

1. Cut the sliding zippers off both bags. One zipper represents the template strands of a DNA molecule.
2. Cut the other zipper into four smaller pieces and unzip each of them. These represent free nucleotides. Don't worry about which nucleotide is which in this activity.
3. Use the pieces to model replication as shown on page 237.

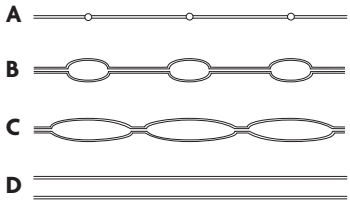
ANALYZE AND CONCLUDE

Evaluate What are the limitations of this model?

MAIN IDEA

Replication is fast and accurate.

FIGURE 8.9 Eukaryotic chromosomes have many origins of replication. The DNA helix is unzipped at many points along each chromosome. The replication "bubbles" grow larger as replication progresses in both directions, resulting in two complete copies.



In every living thing, DNA replication happens over and over again, and it happens remarkably fast. In human cells, about 50 nucleotides are added every second to a new strand of DNA at an origin of replication. But even at this rate, it would take many days to replicate a molecule of DNA if the molecule were like a jacket zipper, unzipping one tooth at a time. Instead, replication proceeds from hundreds of origins of replication along the chromosome, as shown in **FIGURE 8.9**, so the process takes just a few hours.

Another amazing feature of replication is that it has a built-in "proofreading" function to correct errors. Occasionally, the wrong nucleotide is added to the new strand of DNA. However, DNA polymerase can detect the error, remove the incorrect nucleotide, and replace it with the correct one. In this way, errors in replication are limited to about one error per 1 billion nucleotides.

Replication is happening in your cells right now. Your DNA is replicated every time your cells turn over, or replicate themselves. Your DNA has replicated trillions of times since you grew from a single cell.

Infer **Why does a cell need to replicate its DNA quickly?**

8.3 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. Explain the function of **replication.**
2. Explain how DNA serves as its own template during replication. **5.b**
3. How do cells help ensure that DNA replication is accurate?

CRITICAL THINKING

4. **Summarize** Describe two major functions of **DNA polymerases.**
5. **Infer** Why is it important that human chromosomes have many origins of replication?

Connecting CONCEPTS

6. **Cell Biology** DNA is replicated before both mitosis and meiosis. How does the amount of DNA produced in a cell during mitosis compare with that produced during meiosis?