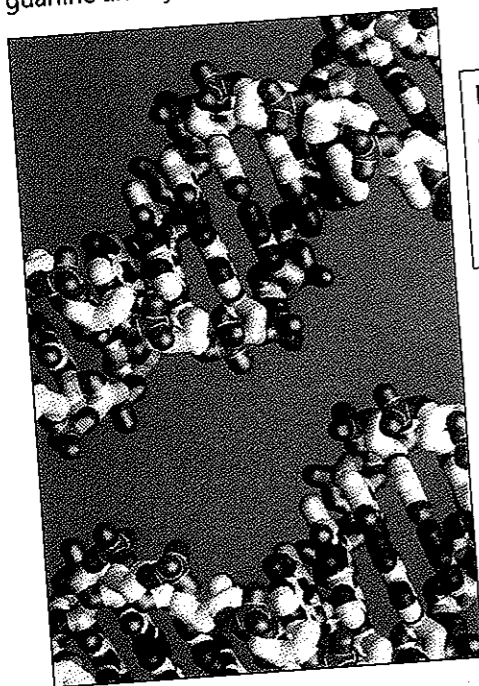
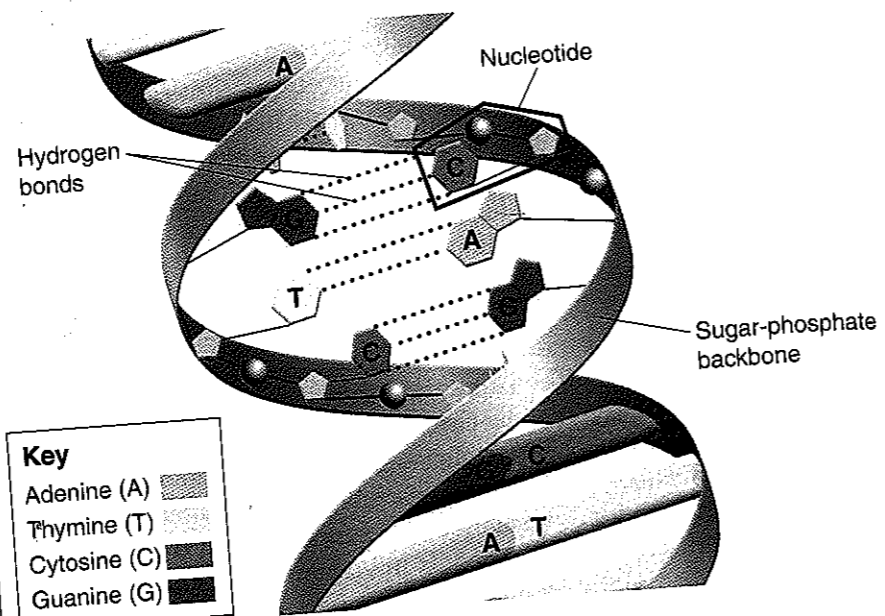


Figure 12-7 DNA is a double helix in which two strands are wound around each other. Each strand is made up of a chain of nucleotides. The two strands are held together by hydrogen bonds between adenine and thymine and between guanine and cytosine.



Key	
Adenine (A)	[Pattern]
Thymine (T)	[Pattern]
Cytosine (C)	[Pattern]
Guanine (G)	[Pattern]

A double helix looks like a twisted ladder or a spiral staircase. When Watson and Crick evaluated their DNA model, they realized that the double helix accounted for many of the features in Franklin's X-ray pattern but did not explain what forces held the two strands together. They then discovered that hydrogen bonds could form between certain nitrogenous bases and provide just enough force to hold the two strands together. As **Figure 12-7** shows, hydrogen bonds can form only between certain base pairs—adenine and thymine, and guanine and cytosine. Once they saw this, they realized that this principle, called **base pairing**, explained Chargaff's rules. Now there was a reason that $[A] = [T]$ and $[G] = [C]$. For every adenine in a double-stranded DNA molecule, there had to be exactly one thymine molecule; for each cytosine molecule, there was one guanine molecule.

12-1 Section Assessment

- Key Concept** List the conclusions Griffith, Avery, Hershey, and Chase drew from their experiments.
- Key Concept** Describe Watson and Crick's model of the DNA molecule.
- What are the four kinds of bases found in DNA?
- Did Watson and Crick's model account for the equal amounts of thymine and adenine in DNA? Explain.

- Critical Thinking Inferring** Why did Hershey and Chase grow viruses in cultures that contained both radioactive phosphorus and radioactive sulfur? What might have happened if they had used only one radioactive substance?

Connecting Concepts

Scientific Methods Using the experiments of Griffith, Avery, or Hershey and Chase as an example, develop a flowchart that shows how the scientist or scientists used scientific processes. Be sure to identify each process. *Hint:* You may wish to review Chapter 1, which describes scientific methods.

12-2 Chromosomes and DNA Replication

DNA is present in such large amounts in many tissues that it's easy to extract and analyze. But where is DNA found in the cell? How is it organized? Where are the genes that Mendel first described a century and a half ago?

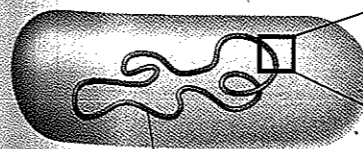
DNA and Chromosomes

Prokaryotic cells lack nuclei and many of the organelles found in eukaryotes. Their DNA molecules are located in the cytoplasm. Most prokaryotes have a single circular DNA molecule that contains nearly all of the cell's genetic information. This large DNA molecule is usually referred to as the cell's chromosome, as shown in **Figure 12-8**.

Eukaryotic DNA is a bit more complicated. Many eukaryotes have as much as 1000 times the amount of DNA as prokaryotes. This DNA is not found free in the cytoplasm. Eukaryotic DNA is generally located in the cell nucleus in the form of a number of chromosomes. The number of chromosomes varies widely from one species to the next. For example, diploid human cells have 46 chromosomes, *Drosophila* cells have 8, and giant sequoia tree cells have 22.

DNA Length DNA molecules are surprisingly long. The chromosome of the prokaryote *E. coli*, which can live in the human colon (large intestine), contains 4,639,221 base pairs. The length of such a DNA molecule is roughly 1.6 mm, which doesn't sound like much until you think about the small size of a bacterium. To fit inside a typical bacterium, the DNA molecule must be folded into a space only one one-thousandth of its length.

Figure 12-8 Most prokaryotes, such as this *E. coli* bacterium, have only a single circular chromosome. This chromosome holds most of the organism's DNA.



Chromosome
E. coli Bacterium

Guide for Reading

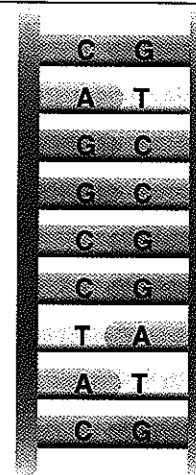
- Key Concept**
- What happens during DNA replication?

Vocabulary

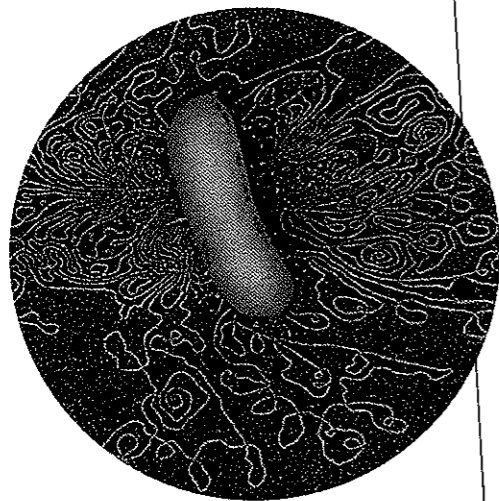
chromatin
histone
replication
DNA polymerase

Reading Strategy:

Asking Questions Before you read, study the diagram in **Figure 12-11**. Make a list of questions about the diagram. As you read, write down the answers to your questions.



Bases on the Chromosome



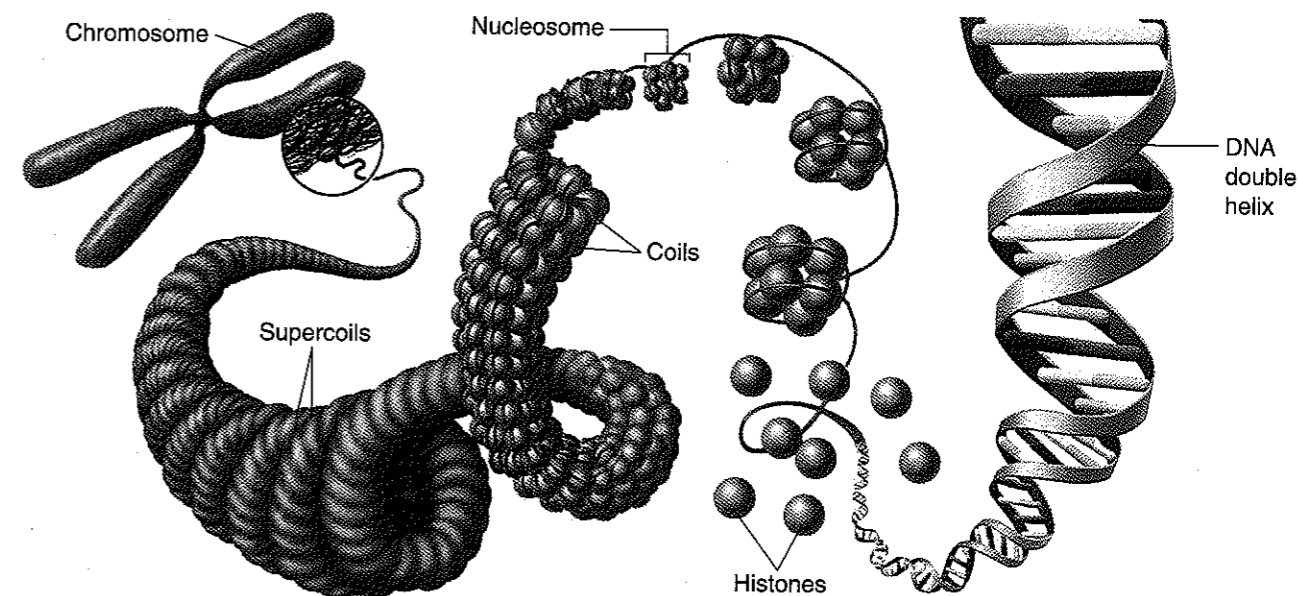
▲ **Figure 12-9** The DNA in a bacterium is about 1000 times as long as the bacterium itself. It must therefore be very tightly folded.
Using Analogies Compare DNA in a bacterium to a rope jammed into a backpack.

To get a rough idea of what this means, think of a large school backpack. Then, imagine trying to pack a 300-meter length of rope into the backpack! **Figure 12-9**, which shows DNA spilling out from a ruptured bacterium, indicates how dramatically the DNA must be folded to fit within the cell.

Chromosome Structure The DNA in eukaryotic cells is packed even more tightly. A human cell contains almost 1000 times as many base pairs of DNA as a bacterium. The nucleus of a human cell contains more than 1 meter of DNA. How is so much DNA folded into tiny chromosomes? The answer can be found in the composition of eukaryotic chromosomes.

Eukaryotic chromosomes contain both DNA and protein, tightly packed together to form a substance called **chromatin**. **Chromatin consists of DNA that is tightly coiled around proteins called histones**, as shown in **Figure 12-10**. Together, the DNA and histone molecules form a beadlike structure called a nucleosome. Nucleosomes pack with one another to form a thick fiber, which is shortened by a system of loops and coils.

During most of the cell cycle, these fibers are dispersed in the nucleus so that individual chromosomes are not visible. During mitosis, however, the fibers of each individual chromosome are drawn together, forming the tightly packed chromosomes you can see through a light microscope in dividing cells. The tight packing of nucleosomes may help separate chromosomes during mitosis. There is also some evidence that changes in chromatin structure and histone-DNA binding are associated with changes in gene activity and expression.



▲ **Figure 12-10** Eukaryotic chromosomes contain DNA wrapped around proteins called histones. The strands of nucleosomes are tightly coiled and supercoiled to form chromosomes.
Interpreting Graphics What is each DNA-histone complex called?

What do nucleosomes do? Nucleosomes seem to be able to fold enormous lengths of DNA into the tiny space available in the cell nucleus. This is such an important function that the histone proteins themselves have changed very little during evolution—probably because mistakes in DNA folding could harm a cell's ability to reproduce.

CHECKPOINT What is chromatin?

DNA Replication

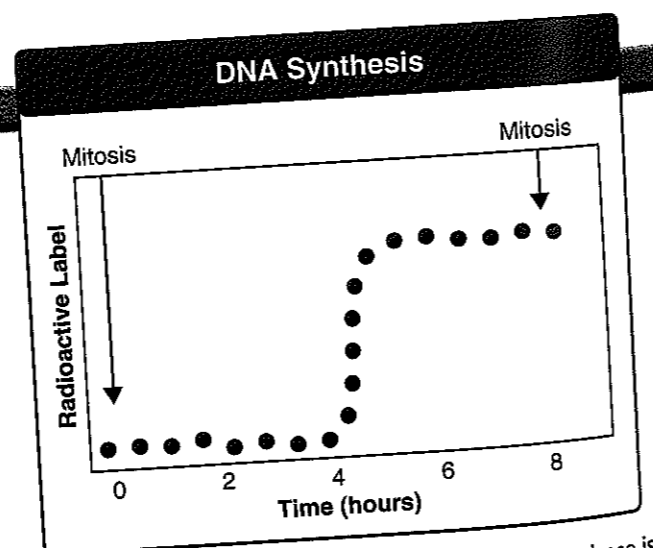
When Watson and Crick discovered the double helix structure of DNA, there was one more remarkable aspect that they recognized immediately. The structure explained how DNA could be copied, or replicated. Each strand of the DNA double helix has all the information needed to reconstruct the other half by the mechanism of base pairing. Because each strand can be used to make the other strand, the strands are said to be complementary. If you could separate the two strands, the rules of base pairing would allow you to reconstruct the base sequence of the other strand.

In most prokaryotes, DNA replication begins at a single point in the chromosome and proceeds, often in two directions, until the entire chromosome is replicated. In the larger eukaryotic chromosomes, DNA replication occurs at hundreds of places. Replication proceeds in both directions until each chromosome is completely copied. The sites where separation and replication occur are called replication forks.

Analyzing Data

Synthesis of New DNA Molecules

How can you investigate when and where cells synthesize DNA? Scientists have done this by briefly adding radioactively labeled thymine to the medium in which a cell grows. A cell that is synthesizing DNA will take the labeled thymine nucleotide into its DNA. The graph shows the total amount of radioactive label taken into DNA from thymine during an eight-hour period between two cell divisions.



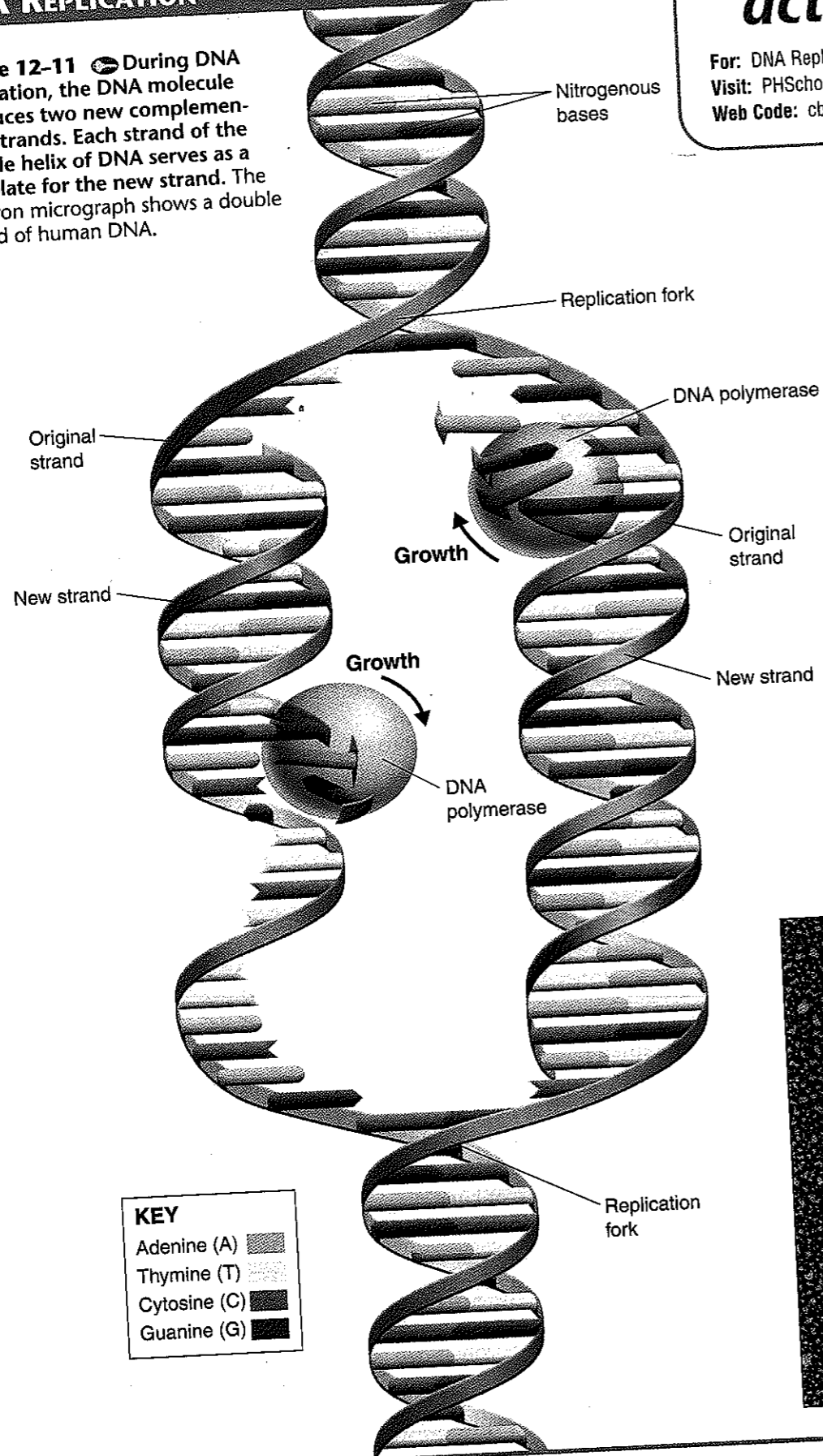
- Interpreting Graphics** Contrast the amounts of radioactivity incorporated during the following times: (a) the first four hours of the experiment, (b) the next two hours, and (c) the final two hours.
- Drawing Conclusions** Is DNA synthesized continually during the cell cycle (the period

- between cell divisions)? If not, during what phase is it synthesized? How long is that phase?
- Predicting** Which organelle or cell structure would you expect to contain the most radioactivity after this experiment? Explain.

Go Online
 For: Links on DNA replication
 Visit: www.SciLinks.org
 Web Code: cbn-4122

DNA REPLICATION

Figure 12-11 During DNA replication, the DNA molecule produces two new complementary strands. Each strand of the double helix of DNA serves as a template for the new strand. The electron micrograph shows a double strand of human DNA.



Go Online
active art

For: DNA Replication activity
Visit: PHSchool.com
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Duplicating DNA Before a cell divides, it duplicates its DNA in a copying process called **replication**. This process ensures that each resulting cell will have a complete set of DNA molecules. During DNA replication, the DNA molecule separates into two strands, then produces two new complementary strands following the rules of base pairing. Each strand of the double helix of DNA serves as a template, or model, for the new strand.

Figure 12-11 shows the process of DNA replication. The two strands of the double helix have separated, allowing two replication forks to form. As each new strand forms, new bases are added following the rules of base pairing. In other words, if the base on the old strand is adenine, thymine is added to the newly forming strand. Likewise, guanine is always paired to cytosine.

For example, a strand that has the bases TACGTT produces a strand with the complementary bases ATGCAA. The result is two DNA molecules identical to each other and to the original molecule. Note that each DNA molecule resulting from replication has one original strand and one new strand.

How Replication Occurs DNA replication is carried out by a series of enzymes. These enzymes “unzip” a molecule of DNA. The unzipping occurs when the hydrogen bonds between the base pairs are broken and the two strands of the molecule unwind. Each strand serves as a template for the attachment of complementary bases.

DNA replication involves a host of enzymes and regulatory molecules. You may recall that enzymes are highly specific. For this reason, they are often named for the reactions they catalyze. The principal enzyme involved in DNA replication is called **DNA polymerase** (PAHL-ih-mur-ayz) because it joins individual nucleotides to produce a DNA molecule, which is, of course, a polymer. DNA polymerase also “proofreads” each new DNA strand, helping to maximize the odds that each molecule is a perfect copy of the original DNA.

12-2 Section Assessment

Thinking Visually

Creating a Venn Diagram

Make a Venn diagram that compares the process of DNA replication in prokaryotes and eukaryotes. Compare the location, steps, and end products of the process in each kind of cell. (For more on Venn diagrams, see Appendix A.)

- Key Concept** Explain how DNA is replicated.
- Where and in what form is eukaryotic DNA found?
- How are the long DNA molecules found in eukaryotes packed into short chromosomes?
- How are histones related to nucleosomes?
- What is the role of DNA polymerase in DNA replication?
- Critical Thinking Comparing and Contrasting** How is the structure of chromosomes in eukaryotes different from the structure of chromosomes in prokaryotes?