Chapter 11

DNA and Genes

What You'll Learn

- You will relate the structure of DNA to its function.
- You will explain the role of DNA in protein production.
- You will distinguish among different types of mutations.

Why It's Important

An understanding of genetic disorders, viral diseases, cancer, aging, genetic engineering, and even criminal investigations depends upon knowing about DNA, how it holds information, and how it plays a role in protein production.

Understanding the Photo

Shetland ponies originated in Shetland—a group of islands off the coast of Scotland. The islands are mostly barren and have extremely cold winters. Due to the isolation of these islands in the past, the characteristics of the pony—small stature, thick hair (coat, mane, and tail), strength, and hardiness—are firmly imprinted in its DNA.

Biology Online

Visit ca.bdol.glencoe.com to

- study the entire chapter online
- access Web Links for more information and activities on DNA and genes
- review content with the Interactive Tutor and self-check quizzes

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Section 11.1

DNA: The Molecule of Heredity

California Standards Standard 5b 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.

SECTION PREVIEW

Objectives

Analyze the structure of DNA.

Determine how the structure of DNA enables it to reproduce itself accurately.

Review Vocabulary

nucleotide: subunit of a nucleic acid formed from a simple sugar, a phosphate group, and a nitrogenous base (p. 163)

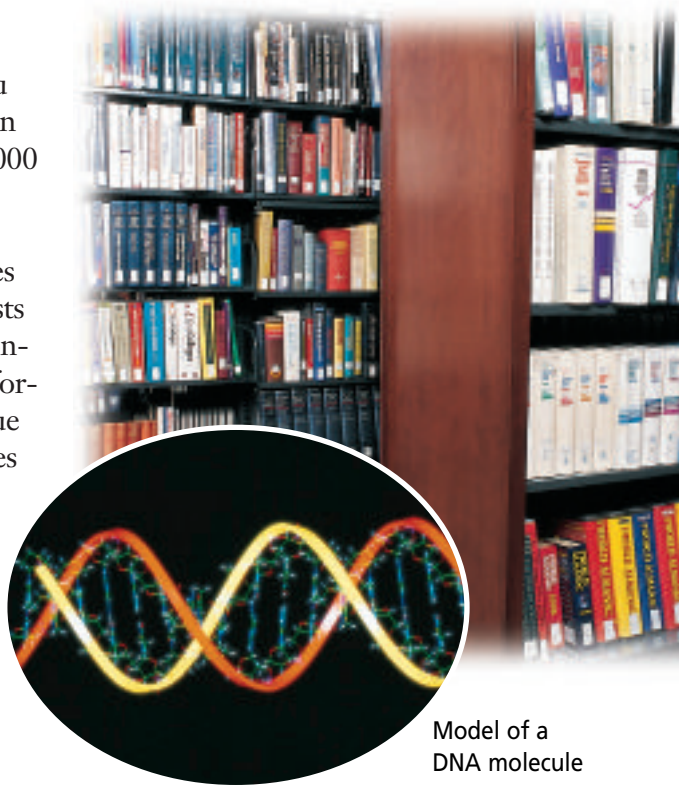
New Vocabulary

nitrogenous base
double helix
DNA replication

Life's Instructions

Using an Analogy Can you imagine all of the information that could be contained in 1000 textbooks? Remarkably, that much information—and more—is carried by the genes of a single organism. Scientists have found that the DNA contained in genes holds this information. Because of the unique structure of DNA, new copies of the information can be easily reproduced.

List *Make a list of current events issues concerning DNA that you may have read about in a newspaper. As you read this section, refer to your list and add explanations from the text.*



Model of a DNA molecule

What is DNA?

Although the environment influences how an organism develops, the genetic information that is held in the molecules of DNA ultimately determines an organism's traits. DNA achieves its control by determining the structure of proteins. Living things contain proteins. Your skin contains protein, your muscles contain protein, and your bones contain protein mixed with minerals. All actions, such as eating, running, and even thinking, depend on proteins called enzymes. Enzymes are critical for an organism's function because they control the chemical reactions needed for life. Within the structure of DNA is the information for life—the complete instructions for manufacturing all the proteins for an organism.

DNA as the genetic material

In the early 1950s, many scientists believed that protein was the genetic material, mainly because the structure of these large molecules was so varied. In 1952, however, Alfred Hershey and Martha Chase performed experiments using radioactively labeled viruses that infect bacteria.

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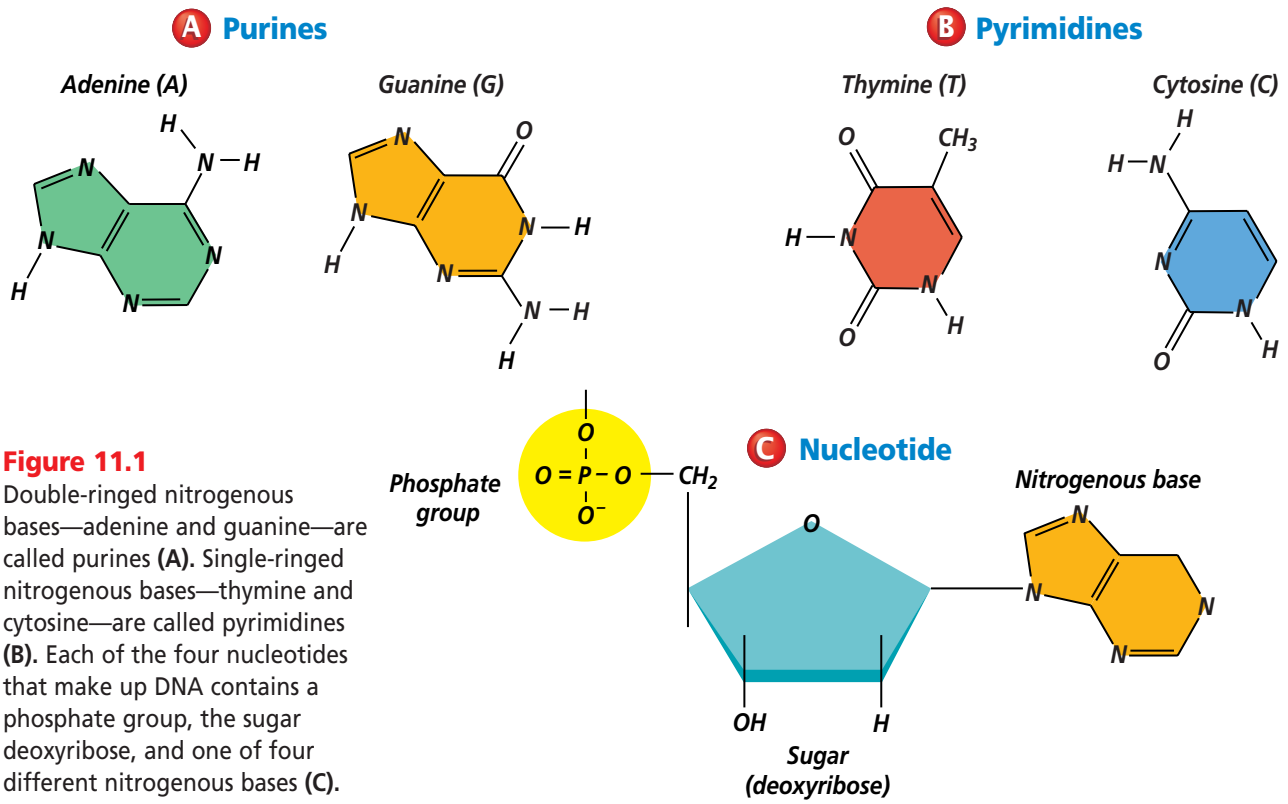

Figure 11.1
Double-ringed nitrogenous bases—adenine and guanine—are called purines **(A).** Single-ringed nitrogenous bases—thymine and cytosine—are called pyrimidines **(B).** Each of the four nucleotides that make up DNA contains a phosphate group, the sugar deoxyribose, and one of four different nitrogenous bases **(C).**

These viruses were made of only protein and DNA. Hershey and Chase created two different types of viruses. One type had radioactive DNA and the other type had radioactive protein. Each type of virus infected a separate bacteria culture. Only the DNA entered the bacteria and produced new viruses. These results were convincing evidence that DNA is the genetic material.

The structure of nucleotides

DNA is capable of holding all its information because it is a very long molecule. Recall that DNA is a polymer made of repeating subunits called nucleotides. Nucleotides have three parts: a simple sugar, a phosphate group, and a nitrogenous base. The simple sugar in DNA, called deoxyribose (dee ahk sih RI bos), gives DNA its name—deoxyribonucleic acid. The phosphate group is composed of one atom of phosphorus surrounded by four oxygen atoms. A **nitrogenous base** is a carbon ring structure that contains one or more atoms of nitrogen. In DNA, there are four possible nitrogenous bases: adenine (A), guanine (G), cytosine (C), and thymine (T). Thus, in DNA there are four possible nucleotides, each containing one of these four bases, as shown in ***Figure 11.1.***

Nucleotides join together to form long chains, with the phosphate group of one nucleotide bonding to the deoxyribose sugar of an adjacent nucleotide. The phosphate groups and deoxyribose molecules form the backbone of the chain, and the nitrogenous bases stick out like the teeth of a zipper. In DNA, the amount of adenine is always equal to the amount of thymine, and the amount of guanine is always equal to the amount of cytosine. You can see this in the *Problem-Solving Lab* on the next page.

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The structure of DNA

In 1953, James Watson and Francis Crick published a letter in a journal that was only one page in length, yet monumental in importance. Watson and Crick proposed that DNA is made of two chains of nucleotides held together by nitrogenous bases. Just as the teeth of a zipper hold the two sides of the zipper together, the nitrogenous bases of the nucleotides hold the two strands of DNA together with weak hydrogen bonds. Hydrogen bonds can form only between certain bases, so the bases on one strand determine the bases on the other strand. Specifically, adenine on one strand pairs only with thymine on the other strand, and guanine on one strand pairs only with cytosine on the other strand. These paired bases, called complementary base pairs, explain why adenine and thymine are always present in equal amounts. Likewise, the guanine-cytosine base pairs result in equal amounts of these nucleotides in DNA. Watson and Crick also proposed that DNA is shaped like a long zipper that is twisted into a coil like a spring. When something is twisted like a spring, the shape is called a helix. Because DNA is composed of two strands twisted together, its shape is called a **double helix.** This shape is shown in ***Figure 11.2.***

The importance of nucleotide sequences

A cattail, a cat, and a catfish are all different organisms composed of different proteins. If you compare the chromosomes of these organisms, you will find that they all contain DNA made up of the same four nucleotides with adenine, thymine, guanine, and cytosine as their nitrogenous bases. How can organisms be so different from each other if their genetic material is made of the same four nucleotides?

Problem-Solving Lab 11.1

Interpret the Data

What does chemical analysis reveal about DNA? Much of the early research on the structure and composition of DNA was done by carrying out chemical analyses. The data from experiments by Erwin Chargaff provided evidence of a relationship among the nitrogenous bases of DNA.

Solve the Problem

Examine the table below. Compare the amounts of adenine, guanine, cytosine, and thymine found in the DNA of each of the cells studied.

Percent of Each Base in DNA Samples

Source of Sample	A	G	C	T
Human liver	30.3	19.5	19.9	30.3
Human thymus	30.9	19.9	19.8	29.4
Herring sperm	27.8	22.2	22.6	27.5
Yeast	31.7	18.2	17.4	32.6

Thinking Critically

1. **Compare and Contrast** Compare the amounts of A, T, G, and C in each kind of DNA. Why do you think the relative amounts are so similar in human liver and thymus cells?
2. **Compare and Contrast** How do the relative amounts of each base in herring sperm compare with the relative amounts of each base in yeast?
3. **Summarize** What fact can you state about the overall composition of DNA, regardless of its source?

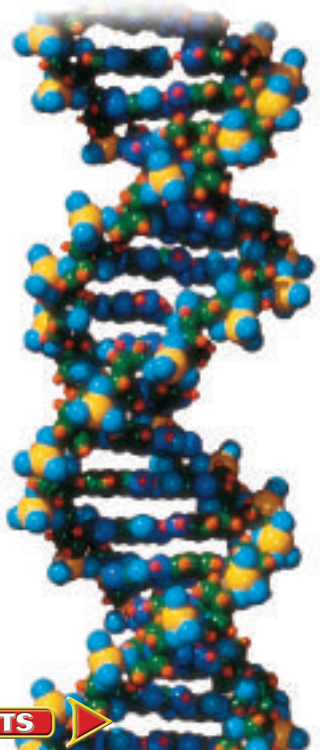

Figure 11.2
DNA normally exists in the shape of a double helix. This shape is similar to that of a twisted zipper.

Their differences result from the sequence of the four different nucleotides along the DNA strands, as shown in ***Figure 11.3.***

The sequence of nucleotides forms the unique genetic information of an organism. For example, a nucleotide sequence of A-T-T-G-A-C carries different information from a sequence of T-C-C-A-A-A. In a similar way, two six-letter words made of the same letters but arranged in different order have different meanings. The closer the relationship is between two organisms, the more similar their DNA nucleotide sequences will be. The DNA sequences of a chimpanzee are similar to those of a gorilla, but different from those of a rosebush. Scientists use nucleotide sequences to determine evolutionary relationships among organisms, to determine whether two people are related, and to identify bodies of crime victims.

Replication of DNA

A sperm cell and an egg cell of two fruit flies, both produced through meiosis, unite to form a fertilized egg. From one fertilized egg, a fruit fly with millions of cells is produced by the process of mitosis. Each cell has a copy of the DNA that was in the original fertilized egg. As you have learned, before a cell can divide by mitosis or meiosis, it must first make a copy of its chromosomes. The DNA in the chromosomes is copied in a process called **DNA replication.** Without DNA replication, new cells would have only half the DNA of their parents. Species could not survive, and

Figure 11.3
The structure of DNA is shown here.

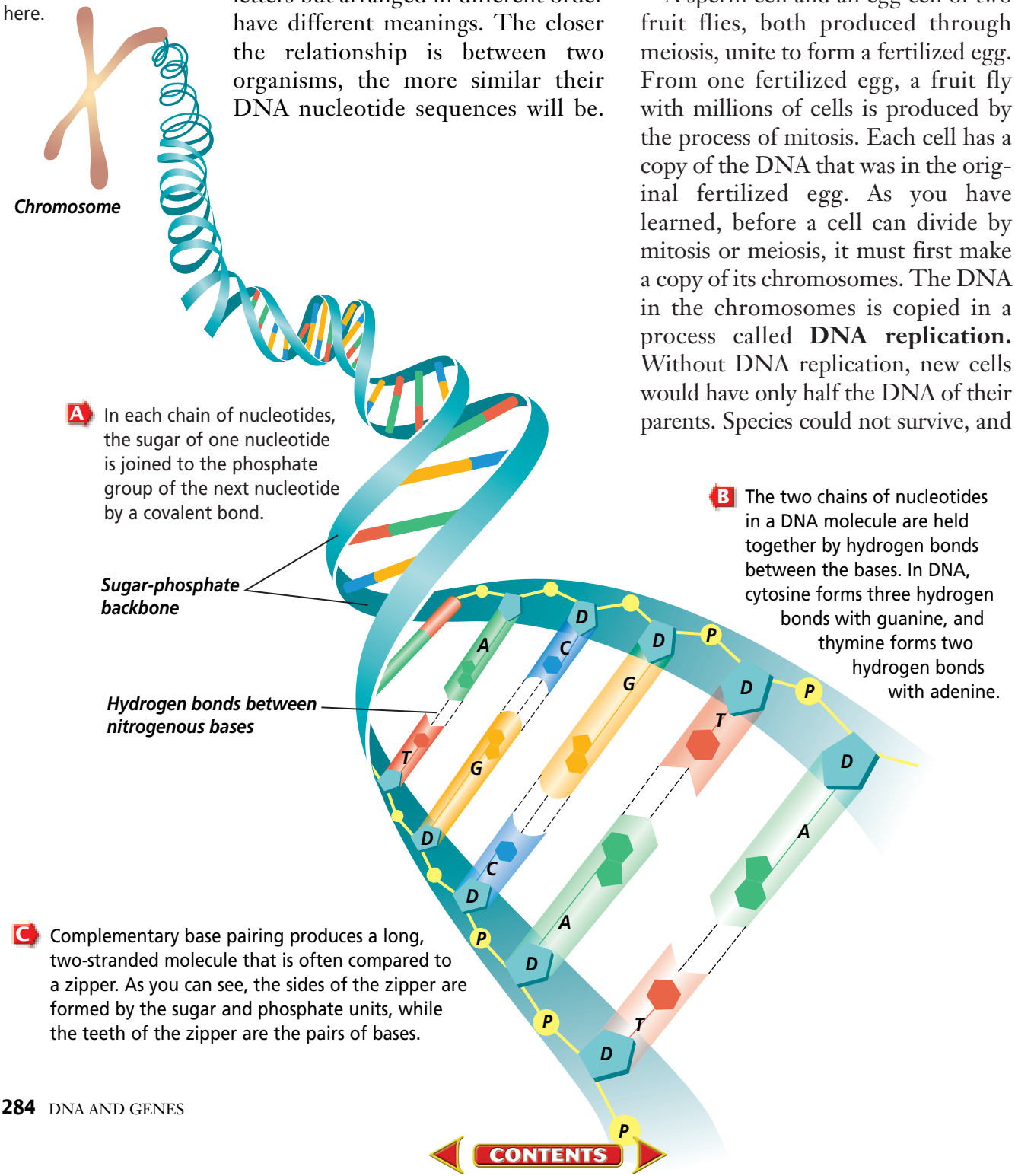

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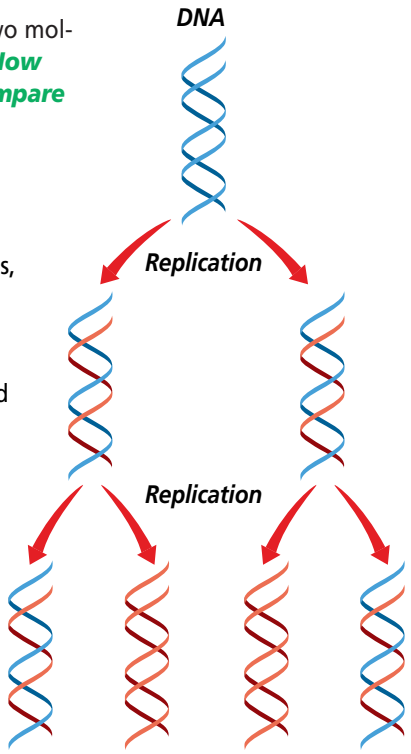
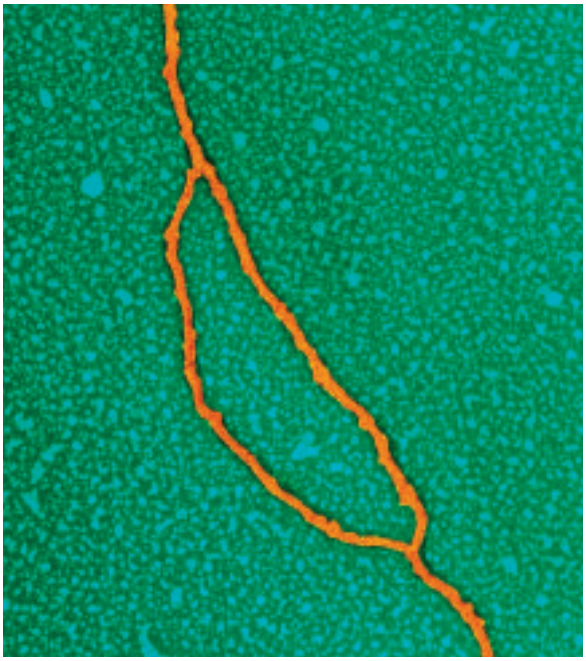
Figure 11.4
DNA replication produces two molecules from one. **Compare** ***How do the new molecules compare with the original?***



A When a DNA molecule replicates, two molecules are formed. Each molecule has one original strand and one new strand. Newly synthesized strands are shown in red.

B This DNA is replicating. Replication is taking place at the points where the DNA has unzipped to create a "bubble."



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individuals could not grow or reproduce successfully. All organisms undergo DNA replication. ***Figure 11.4B*** shows bacterial DNA replicating.

How DNA replicates

You have learned that a DNA molecule is composed of two strands, each containing a sequence of nucleotides. As you know, an adenine on one strand pairs with a thymine on the other strand. Similarly, guanine pairs with cytosine. Therefore, if you know the order of bases on one strand, you can predict the sequence of bases on the other, complementary strand. In fact, part of the process of DNA replication is done in just the same way. During replication, each strand serves as a pattern, or template, to make a new DNA molecule. How can a molecule serve as a template? Examine ***Figure 11.5*** on the next page to find out.

Replication begins as an enzyme breaks the hydrogen bonds between bases that hold the two strands together, thus unzipping the DNA. As the DNA continues to unzip, nucleotides that are floating free in the surrounding medium are attached to their base pair by hydrogen bonding. Another enzyme bonds these nucleotides into a chain.

This process continues until the entire molecule has been unzipped and replicated. Each new strand formed is a complement of one of the original, or parent, strands. The result is the formation of two DNA molecules, each of which is identical to the original DNA molecule.

When all the DNA in all the chromosomes of the cell has been copied by replication, there are two copies of the organism's genetic information. In this way, the genetic makeup of an organism can be passed on to new cells during mitosis or to new generations through meiosis followed by sexual reproduction.

Reading Check **Explain** why DNA must unzip before it can be copied.

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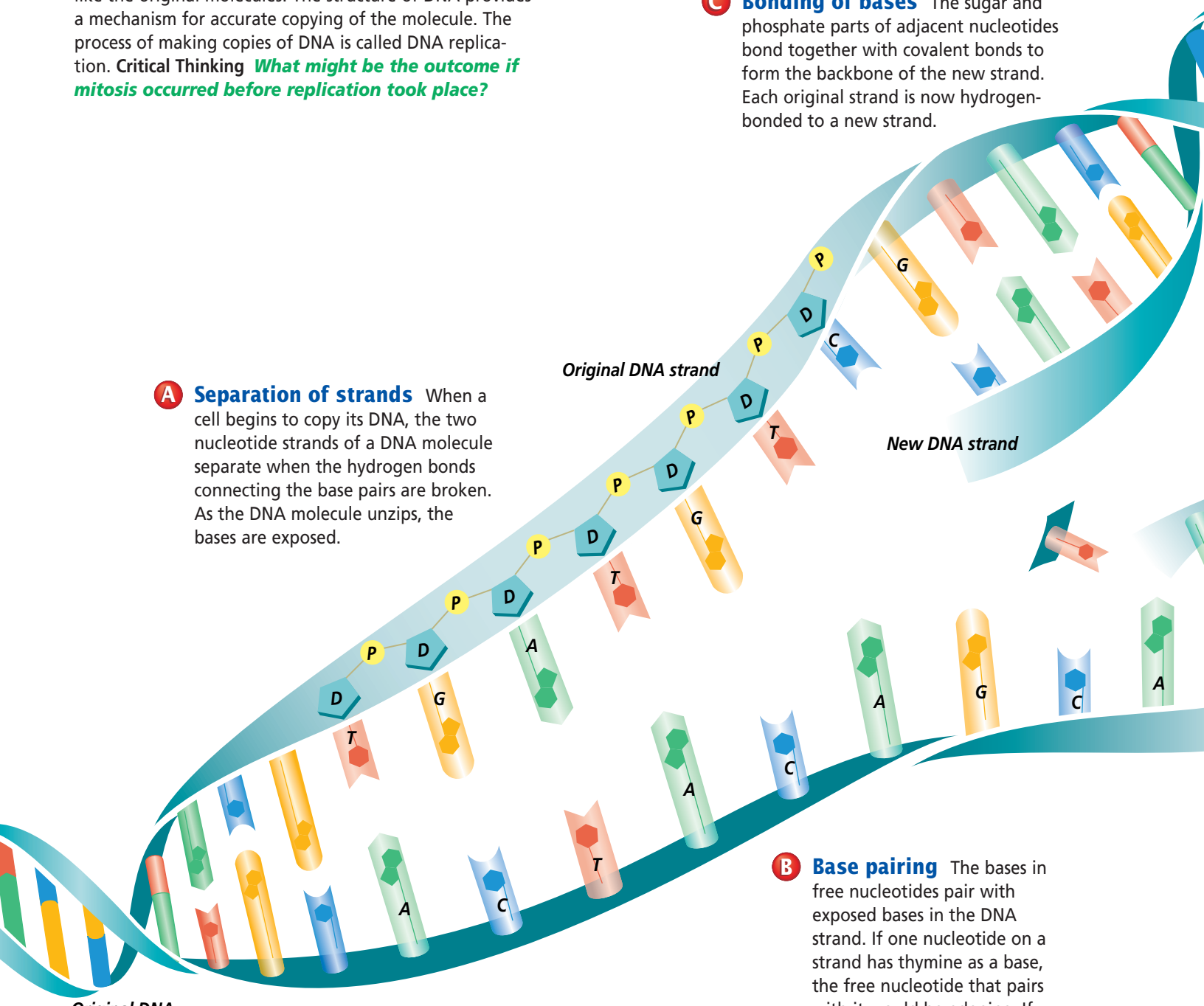
Copying DNA

Figure 11.5

DNA is copied during interphase prior to mitosis and meiosis. It is important that the new copies are exactly like the original molecules. The structure of DNA provides a mechanism for accurate copying of the molecule. The process of making copies of DNA is called DNA replication. **Critical Thinking** ***What might be the outcome if mitosis occurred before replication took place?***



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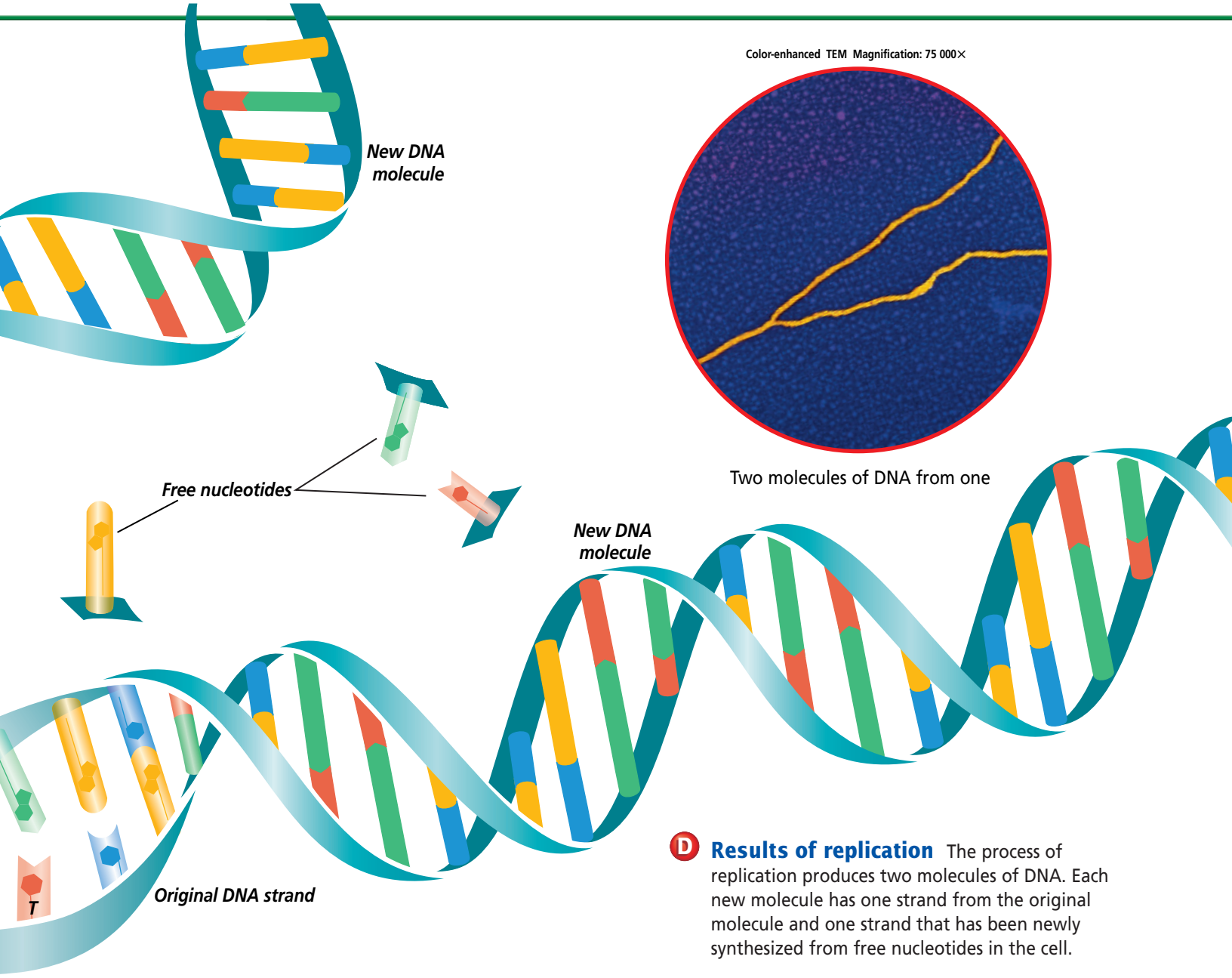

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Two molecules of DNA from one

D **Results of replication** The process of replication produces two molecules of DNA. Each new molecule has one strand from the original molecule and one strand that has been newly synthesized from free nucleotides in the cell.

Section Assessment

Understanding Main Ideas

1. Describe the structure of a nucleotide.
2. How do the nucleotides in DNA bond with each other within a strand? How do they bond with each other across strands?
3. Explain why the structure of a DNA molecule is often described as a zipper.
4. How does DNA hold information?

Thinking Critically

5. The sequence of nitrogenous bases on one strand of a DNA molecule is GGCAGTTCATGC. What would be the sequence of bases on the complementary strand?

Skill Review

6. **Get the Big Picture** Sequence the steps that occur during DNA replication. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

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Section 11.2

From DNA to Protein

California Standards Standard 4b Students know how to apply the genetic coding rules to predict the sequence of amino acids from a sequence of codons in RNA.

SECTION PREVIEW

Objectives

Relate the concept of the gene to the sequence of nucleotides in DNA.

Sequence the steps involved in protein synthesis.

Review Vocabulary

polymer: a large molecule formed from smaller sub-units that are bonded together (p. 158)

New Vocabulary

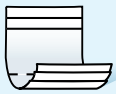
messenger RNA
ribosomal RNA
transfer RNA
transcription
codon
translation

FOLDABLES Study Organizer

Protein Synthesis Make the following Foldable to help you understand the process of protein formation.

STEP 1 **Collect** 3 sheets of paper and layer them about 1.5 cm apart vertically. Keep the edges level.

STEP 2 **Fold** up the bottom edges of the paper to form 6 equal tabs.



STEP 3 **Fold** the papers and crease well to hold the tabs in place. Staple along the fold. **Label** each tab.

Sequence After you read Section 11.2, begin at the top tab and sequence the five steps of translation.

Genes and Proteins

The sequence of nucleotides in DNA contain information. This information is put to work through the production of proteins. Proteins fold into complex, three-dimensional shapes to become key structures and regulators of cell functions. Some proteins become important structures, such as the filaments in muscle tissue. Other proteins, such as enzymes, control chemical reactions that perform key life functions—breaking down glucose molecules in cellular respiration, digesting food, or making spindle fibers during mitosis. In fact, enzymes control all the chemical reactions of an organism. Thus, by encoding the instructions for making proteins, DNA controls cells.

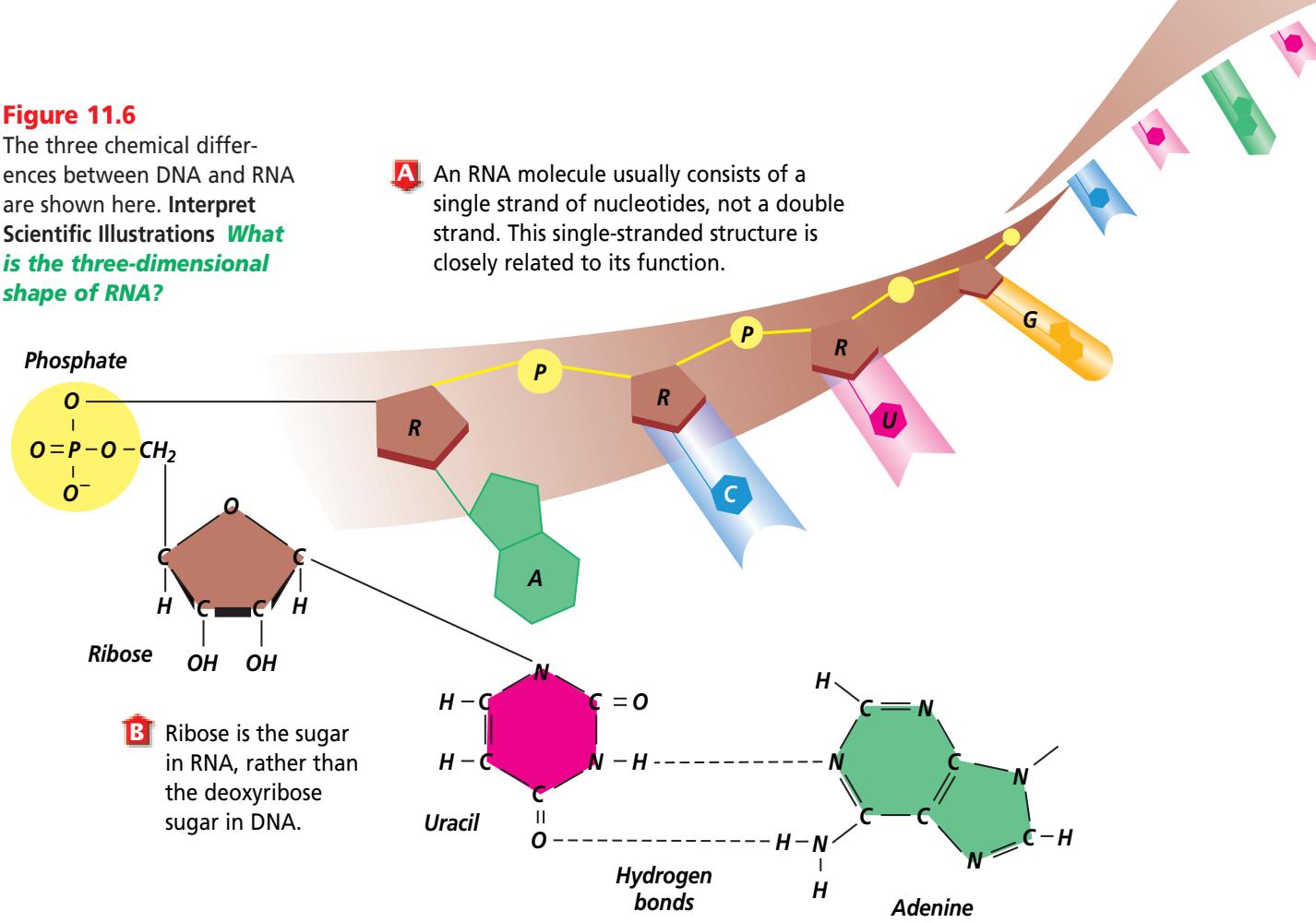
You learned earlier that proteins are polymers of amino acids. The sequence of nucleotides in each gene contains information for assembling the string of amino acids that make up a single protein.

Reading Check **Explain** how DNA controls the activities of cells.

RNA

RNA, like DNA, is a nucleic acid. However, RNA structure differs from DNA structure in three ways, shown in ***Figure 11.6.*** First, RNA is single stranded—it looks like one-half of a zipper—whereas DNA is double stranded. The sugar in RNA is ribose; DNA's sugar is deoxyribose.

Figure 11.6
The three chemical differences between DNA and RNA are shown here. **Interpret Scientific Illustrations** ***What is the three-dimensional shape of RNA?***



Finally, both DNA and RNA contain four nitrogenous bases, but rather than thymine, RNA contains a similar base called uracil (U). Uracil forms a base pair with adenine in RNA, just as thymine does in DNA.

What is the role of RNA in a cell? Perhaps you have seen a car being built on an automobile assembly line. Complex automobiles are built in many simple steps. Engineers tell workers how to make the cars, and workers follow directions to build the cars on the assembly line. Suppliers bring parts to the assembly line so they can be installed in the car. Protein production is similar to car production. DNA provides workers with the instructions for making the proteins, and workers build the proteins. Other workers bring parts, the amino acids, over to the assembly line. The workers for protein synthesis are RNA molecules. They take from DNA the instructions on how the protein should be assembled, then—amino acid by amino acid—they assemble the protein.

There are three types of RNA that help build proteins. Extending the car-making analogy, you can consider all three of these RNA molecules to be workers in the protein assembly line. One type of RNA, **messenger RNA** (mRNA), brings instructions from DNA in the nucleus to the cell's factory floor, the cytoplasm. On the factory floor, mRNA moves to the assembly line, a ribosome.

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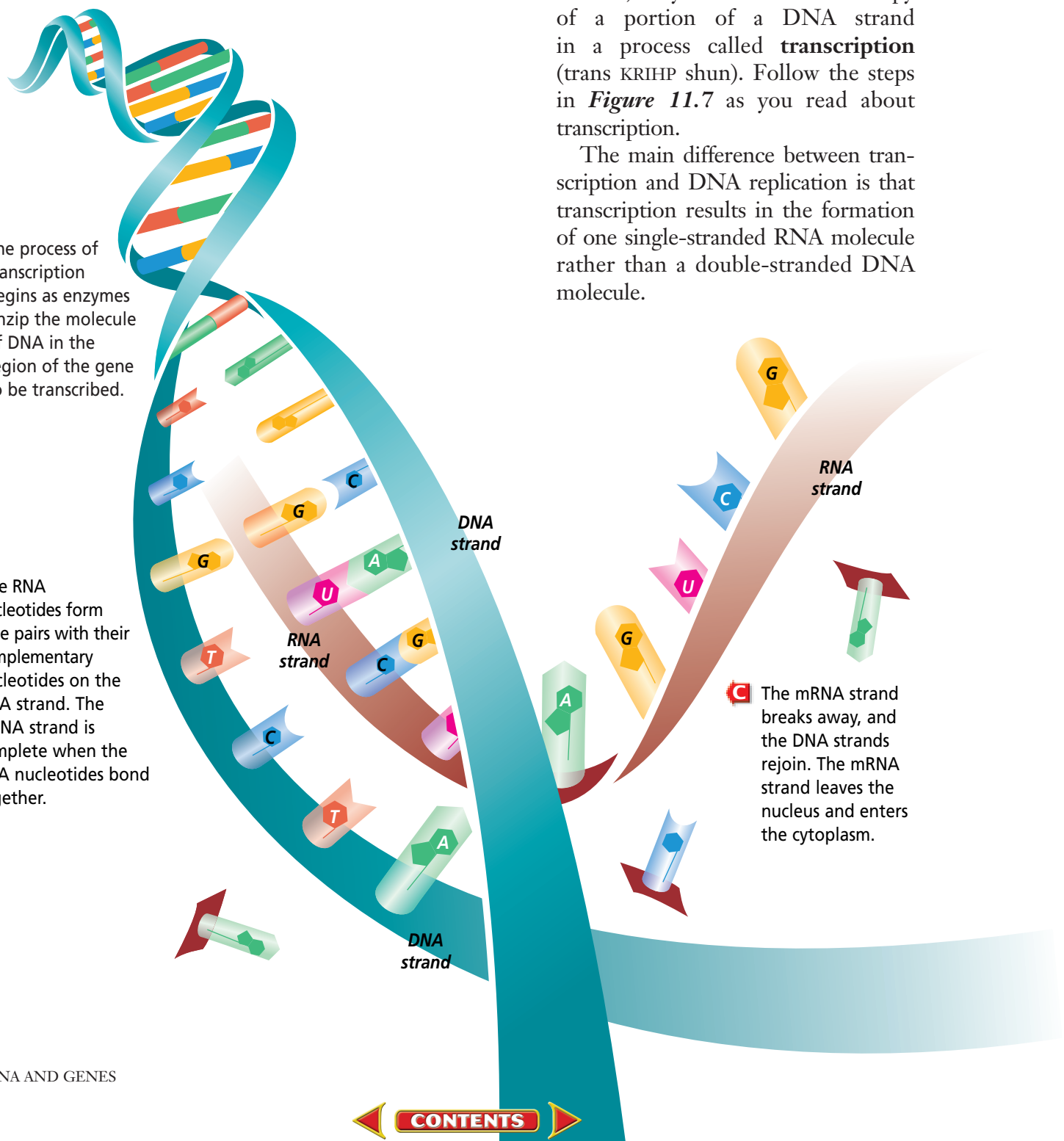
The ribosome, made of **ribosomal RNA** (rRNA), binds to the mRNA and uses the instructions to assemble the amino acids in the correct order. The third type of RNA, **transfer RNA** (tRNA) is the supplier. Transfer RNA delivers amino acids to the ribosome to be assembled into a protein.

Transcription

How does the information in DNA, which is found in the nucleus, move to the ribosomes in the cytoplasm? Messenger RNA carries this information through the nuclear envelope to the ribosomes for manufacturing proteins, just as a worker carries information from the engineers to the assembly line for manufacturing a car. In the nucleus, enzymes make an RNA copy of a portion of a DNA strand in a process called **transcription** (trans KRIHP shun). Follow the steps in ***Figure 11.7*** as you read about transcription.

The main difference between transcription and DNA replication is that transcription results in the formation of one single-stranded RNA molecule rather than a double-stranded DNA molecule.

Figure 11.7
Messenger RNA is made during the process of transcription.



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Modeling transcription in the *BioLab* on pages 302–303 will help you to understand this process. You can find out how scientists use new microscopes to "watch" transcription take place by reading the *Biotechnology* at the end of the chapter.

RNA Processing

Not all the nucleotides in the DNA of eukaryotic cells carry instructions—or code—for making proteins. Genes usually contain many long noncoding nucleotide sequences, called introns (for *in*tervening regions), that are scattered among the coding sequences. Regions that contain information are called exons because they are *ex*pressed. When mRNA is transcribed from DNA, both introns and exons are copied. The introns must be removed from the mRNA before it can function to make a protein. Enzymes in the nucleus cut out the intron segments and paste the mRNA back together. The mRNA then leaves the nucleus and travels to the ribosome.

The Genetic Code

The nucleotide sequence transcribed from DNA to a strand of messenger RNA acts as a genetic message, the complete information for the building of a protein. Think of this message as being written in a language that uses nitrogenous bases as its alphabet. As you know, proteins contain chains of amino acids. You could say that the language of proteins uses an alphabet of amino acids. A code is needed to convert the language of mRNA into the language of proteins. There are 20 common amino acids, but mRNA contains only four types of bases. How can four bases form a code for all possible proteins? The *Problem-Solving Lab* shows you how.

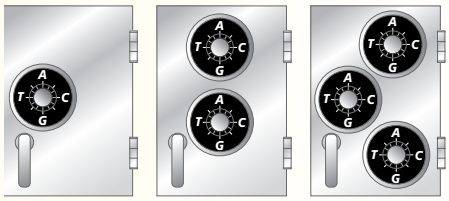
Problem-Solving Lab 11.2

Formulate Models

How many nitrogenous bases determine an amino acid?
After the structure of DNA had been discovered, scientists tried to predict the number of nucleotides that code for a single amino acid. It was already known that there were 20 amino acids, so at least 20 groups were needed. If one nucleotide coded for an amino acid, then only four amino acids could be represented. How many nucleotides are needed?

Solve the Problem

Examine the three safes. Letters representing nitrogenous bases have replaced numbers on the dials. Copy the data table. Calculate the possible number of combinations that will open the safe in each diagram using the formula provided in the table. The *4* corresponds to the number of letters on each dial; the superscript refers to the number of available dials.



Safe 1 Safe 2 Safe 3

Data Table

	Number of Dials	Number of Letters per Dial	Total Possible Combinations	Formula
Safe 1				4^1
Safe 2				4^2
Safe 3				4^3

Thinking Critically

1. **Use Models** Using Safe 1, write down several examples of dial settings that might open the safe. Do the total possible combinations seen in Safe 1 equal or surpass the total number of common amino acids?
2. **Analyze** Could a nitrogenous base (A, T, C, or G) taken one at a time code for 20 different amino acids? Explain.
3. **Use Numbers** Using Safe 2, write down several examples of dial combinations that might open the safe. Do the total possible combinations seen in Safe 2 equal or surpass the total number of common amino acids?
4. **Analyze** Could nitrogenous bases taken two at a time code for 20 different amino acids? Explain.
5. **Analyze** Could nitrogenous bases taken three at a time code for 20 different amino acids? Explain.
6. **Draw Conclusions** Does the analogy prove that three bases code for an amino acid? Explain.

Biochemists began to crack the genetic code when they discovered that a group of three nitrogenous bases in mRNA code for one amino acid. Each group is known as a **codon.** For example, the codon UUU results in the amino acid phenylalanine being placed in a protein.

Sixty-four combinations are possible when a sequence of three bases is used; thus, 64 different mRNA codons are in the genetic code, shown in ***Table 11.1.*** Some codons do not code for amino acids; they provide instructions for making the protein. For example, UAA is a *stop* codon indicating that the protein chain ends at that point. AUG is a *start* codon as well as the codon for the amino acid methionine. As you can see, more than one codon can code for the same amino acid. However, for any one codon, there can be only one amino acid.

All organisms use the same genetic code. For this reason, it is said to be universal, and this provides evidence that all life on Earth evolved from a common origin. From the chlorophyll of a birch tree to the digestive enzymes of a bison, a large number of proteins are produced from DNA. It may be hard to imagine that only four nucleotides can produce so many diverse proteins; yet, think about computer programming. You may have seen computer code, such as 00010101110000110. Through a binary language with only two options—zeros and ones—many types of software are created. From computer games to World Wide Web browsers, complex software is built by stringing together the zeros and ones of computer code into long chains. Likewise, complex proteins are built from the long chains of DNA carrying the genetic code.

Table 11.1 The Messenger RNA Genetic Code

First Letter	Second Letter				Third Letter
	U	C	A	G	
U	Phenylalanine (UUU)	Serine (UCU)	Tyrosine (UAU)	Cysteine (UGU)	U
	Phenylalanine (UUC)	Serine (UCC)	Tyrosine (UAC)	Cysteine (UGC)	C
	Leucine (UUA)	Serine (UCA)	Stop (UAA)	Stop (UGA)	A
	Leucine (UUG)	Serine (UCG	Stop (UAG)	Tryptophan (UGG)	G
C	Leucine (CUU)	Proline (CCU)	Histidine (CAU)	Arginine (CGU)	U
	Leucine (CUC)	Proline (CCC)	Histidine (CAC)	Arginine (CGC)	C
	Leucine (CUA)	Proline (CCA)	Glutamine (CAA)	Arginine (CGA)	A
	Leucine (CUG)	Proline (CCG)	Glutamine (CAG)	Arginine (CGG)	G
A	Isoleucine (AUU)	Threonine (ACU)	Asparagine (AAU)	Serine (AGU)	U
	Isoleucine (AUC)	Threonine (ACC)	Asparagine (AAC)	Serine (AGC)	C
	Isoleucine (AUA)	Threonine (ACA)	Lysine (AAA)	Arginine (AGA)	A
	Methionine; Start (AUG)	Threonine (ACG)	Lysine (AAG)	Arginine (AGG)	G
G	Valine (GUU)	Alanine (GCU)	Aspartate (GAU)	Glycine (GGU)	U
	Valine (GUC)	Alanine (GCC)	Aspartate (GAC)	Glycine (GGC)	C
	Valine (GUA)	Alanine (GCA)	Glutamate (GAA)	Glycine (GGA)	A
	Valine (GUG)	Alanine (GCG)	Glutamate (GAG)	Glycine (GGG)	G

Translation: From mRNA to Protein

How is the language of the nucleic acid mRNA translated into the language of proteins? The process of converting the information in a sequence of nitrogenous bases in mRNA into a sequence of amino acids in protein is known as **translation.** You can summarize transcription and translation by completing the *MiniLab*.

Translation takes place at the ribosomes in the cytoplasm. In prokaryotic cells, which have no nucleus, the mRNA is made in the cytoplasm. In eukaryotic cells, mRNA is made in the nucleus and travels to the cytoplasm. In the cytoplasm, a ribosome attaches to the strand of mRNA like a clothespin clamped onto a clothesline.

The role of transfer RNA

For proteins to be built, the 20 different amino acids dissolved in the cytoplasm must be brought to the ribosomes. This is the role of transfer RNA (tRNA), modeled in ***Figure 11.8.*** Each tRNA molecule attaches to only one type of amino acid.

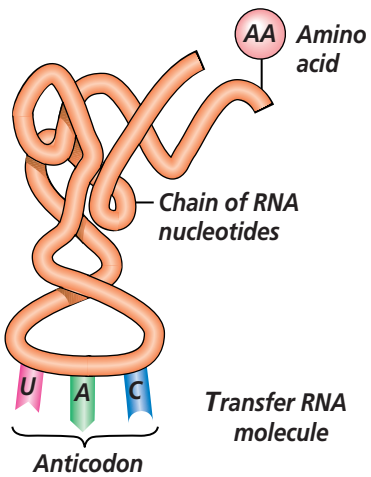


Figure 11.8
A tRNA molecule is composed of about 80 nucleotides. Each tRNA recognizes only one amino acid. The amino acid becomes bonded to one side of the tRNA molecule. Located on the other side of the tRNA molecule are three nitrogenous bases, called an anticodon, that pair up with an mRNA codon during translation.

MiniLab 11.1

Predict

Transcribe and Translate Molecules of DNA carry the genetic instructions for protein formation. Converting these DNA instructions into proteins requires a series of coordinated steps in transcription and translation.

Procedure

1. Copy the data table.
2. Complete column B by writing the correct mRNA codon for each sequence of DNA bases listed in the column marked *DNA Base Sequence.* Use the letters A, U, C, or G.
3. Identify the process responsible by writing its name on the arrow in column A.
4. Complete column D by writing the correct anticodon that binds to each codon from column B.
5. Identify the process responsible by writing its name on the arrow in column C.
6. Complete column E by writing the name of the correct amino acid that is coded by each base sequence. Use ***Table 11.1*** on page 292 to translate the mRNA base sequences to amino acids.

Data Table

	A	B	C	D	E
DNA Base Sequence	Process	mRNA Codon	Process	tRNA Anticodon	Amino Acid
AAT	→		→		
GGG	→		→		
ATA	→		→		
AAA	→		→		
GTT	→		→		

Analysis

1. **Recognize Spatial Relationships** Where within the cell:
   - **a.** are the DNA instructions located?
   - **b.** does transcription occur?
   - **c.** does translation occur?
2. **Formulate Models** Describe the structure of a tRNA molecule.
3. **Use Scientific Explanations** Explain why specific base pairing is essential to the processes of transcription and translation.

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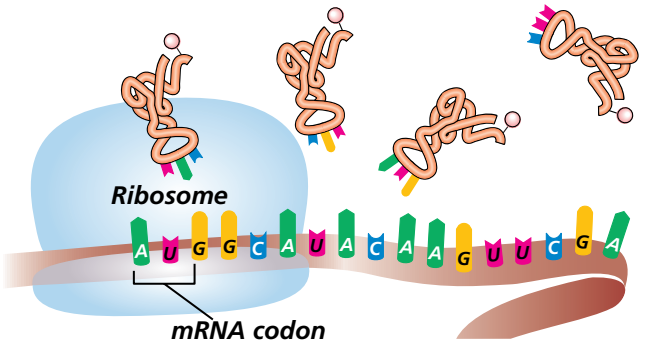
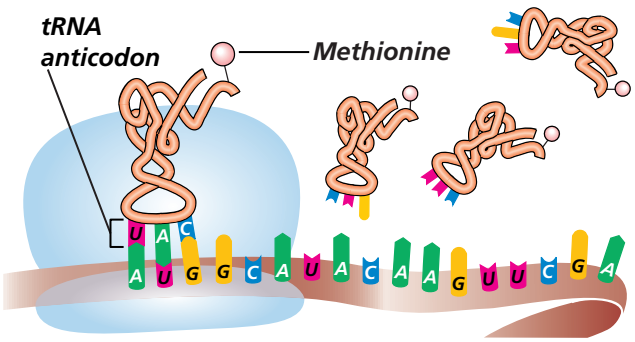
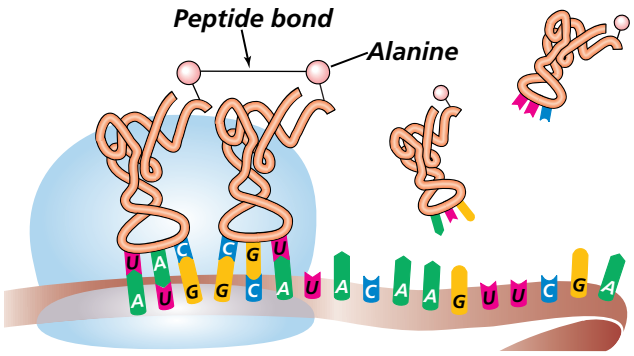
Figure 11.9
A protein is formed by the process of translation.

A As translation begins, a ribosome attaches to the mRNA strand. Molecules of tRNA, each carrying a specific amino acid, approach the ribosome.

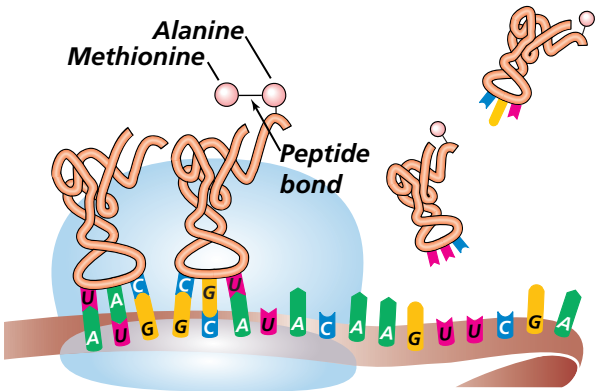




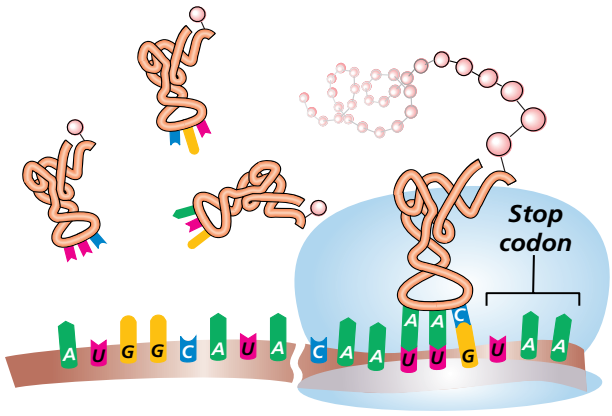
B The codon AUG, which codes for the amino acid methionine, signals the start of protein synthesis. The tRNA molecule carrying methionine attaches to the ribosome and mRNA strand.



C A new tRNA molecule carrying an amino acid attaches to the ribosome and mRNA strand next to the previous tRNA molecule. The amino acids on the tRNA molecules join by peptide bonds.



D After the peptide bond is formed, the ribosome slides along the mRNA to the next codon. The tRNA molecule no longer carrying an amino acid is released. A new tRNA molecule carrying an amino acid can attach to the ribosome and mRNA strand.



E A chain of amino acids is formed until a stop codon is reached on the mRNA strand.

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Correct translation of the mRNA message depends upon the joining of each mRNA codon with the correct tRNA molecule. How does a tRNA molecule carrying its amino acid recognize which codon to attach to? The answer involves base pairing. There is a sequence of three nucleotides on the opposite side of the transfer-RNA molecule from the amino-acid attachment site, that is the complement of the nucleotides in the codon. These three nucleotides are called an anticodon because they bind to the codon of the mRNA. The tRNA carries only the amino acid that the anticodon specifies. For example, one tRNA molecule for the amino acid cysteine has an anticodon of ACA. This anticodon binds to the mRNA codon UGU.

Translating the mRNA code

Follow the steps in ***Figure 11.9*** as you read how translation occurs. As translation begins, a tRNA molecule brings the first amino acid to the mRNA strand that is attached to the ribosome, ***Figure 11.9A.*** The anticodon forms a base pair with the codon of the mRNA strand, ***Figure 11.9B.*** This places the amino acid in the correct position for forming a peptide bond with the next amino acid. The ribosome slides down the mRNA chain to the next codon, and a new tRNA molecule brings another amino acid, ***Figure 11.9C.*** The amino acids bond; the first tRNA releases its amino acid and detaches from the mRNA, ***Figure 11.9D.*** The tRNA molecule is now free to pick up and deliver another molecule of its specific amino acid to a ribosome. Again, the ribosome slides down to the next codon; a new tRNA molecule arrives, and its amino acid bonds to the previous one. A chain of amino acids begins to form. When a *stop* codon is reached, translation ends, and the amino acid strand is released from the ribosome, ***Figure 11.9E.***

Amino acid chains become proteins when they are freed from the ribosome and twist and curl into complex three-dimensional shapes. Each protein chain forms the same shape every time it is produced. These proteins become enzymes and cell structures.

Now that you have followed the process of protein synthesis, you have seen that the pathway of information flows from DNA to mRNA to protein. This scheme is called the central dogma of biology and is found in all organisms from the simplest bacterium to the most complex plant and animal. The formation of protein, originating from the DNA code, produces the diverse and magnificent living world.

Word Origin

codon from the Latin word *codex,* meaning "a tablet for writing"; A codon is the three-nucleotide sequence that codes for an amino acid.

Section Assessment

Understanding Main Ideas

1. How does the DNA nucleotide sequence determine the amino acid sequence in a protein?
2. What is a codon, and what does it represent?
3. What is the role of tRNA in protein synthesis?
4. Compare DNA replication and transcription.

Thinking Critically

5. You have learned that there are *stop* codons that signal the end of an amino acid chain. Why is it important that a signal to stop translation be part of protein synthesis?

Skill Review

6. **Get the Big Picture** Sequence the steps involved in protein synthesis from the production of mRNA to the final translation of the DNA code. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

Section 11.3

Genetic Changes

California Standards Standard 4c Students know how mutations in the DNA sequence of a gene may or may not affect the expression of the gene or the sequence of amino acids in an encoded protein.

SECTION PREVIEW

Objectives

Categorize the different kinds of mutations that can occur in DNA.

Compare the effects of different kinds of mutations on cells and organisms.

Review Vocabulary

cancer: diseases believed to be caused by changes in the genes that control the cell cycle (p. 211)

New Vocabulary

mutation
point mutation
frameshift mutation
chromosomal mutation
mutagen

When Things Go Wrong

Using Prior Knowledge You know that DNA controls the structures and functions of a cell. What happens when the sequence of DNA nucleotides in a gene is changed? Sometimes it may have little or no harmful effect—like the thick, tightly crimped fur on this American Wirehair cat—and the DNA changes are passed on to offspring of the organism. At other times, however, the change can cause the cell to behave differently. For example, in skin cancer, UV rays from the sun damage the DNA and cause the cells to grow and divide rapidly.

American Wirehair cat

Recognize Cause and Effect *Why might a mutation have little or no harmful effect on an organism?*

Mutations

If the DNA in all the cells of an adult human body were lined up end to end, it would stretch nearly 100 billion kilometers—60 times the distance from Earth to Jupiter. This DNA is the end result of thousands of replications, beginning with the DNA in a fertilized egg. Organisms have evolved many ways to protect their DNA from changes. In spite of these mechanisms, however, changes in the DNA occasionally do occur. Any change in the DNA sequence is called a **mutation.** Mutations can be caused by errors in replication, transcription, cell division, or by external agents. One such cause is discussed in ***Figure 11.10.***

Physical Science Connection

Gamma radiation as a wave
Gamma radiation, or gamma rays, are electromagnetic waves. Gamma radiation is emitted by processes that occur in the nuclei of atoms. They have the shortest wavelengths and highest frequencies of any waves in the electromagnetic spectrum.

Mutations in reproductive cells

Mutations can affect the reproductive cells of an organism by changing the sequence of nucleotides within a gene in a sperm or an egg cell. If this cell takes part in fertilization, the altered gene would become part of the genetic makeup of the offspring. The mutation may produce a new trait or it may result in a protein that does not work correctly, resulting in structural or functional problems in cells and in the organism. Sometimes, the mutation results in a protein that is nonfunctional, and the embryo may not survive.

In some rare cases, a gene mutation may have positive effects. An organism may receive a mutation that makes it faster or stronger; such a mutation may help an organism—and its offspring—better survive in its environment.

Richard Katris

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Figure 11.10
Nuclear power plant workers wear radiation badges **(A)** and pocket dosimeters **(B)** to monitor their exposure to radiation. Radiation can cause changes to DNA.

You will learn later that mutations that benefit a species play an important role in the evolution of that species.

Mutations in body cells

What happens if powerful radiation, such as gamma radiation, hits the DNA of a nonreproductive cell, a cell of the body such as in skin, muscle, or bone? If the cell's DNA is changed, this mutation would not be passed on to offspring. However, the mutation may cause problems for the individual. Damage to a gene may impair the function of the cell; for example, it may cause a cell in the stomach to lose its ability to make acid needed for digestion, or a skin cell may lose its elasticity. When that cell divides, the new cells also will have the same mutation. Many scientists suggest that the buildup of cells with less than optimal functioning is an important cause of aging.

Some mutations of DNA in body cells affect genes that control cell division. This can result in the cells growing and dividing rapidly, producing cancer. As you learned earlier, cancer is the uncontrolled dividing of cells.

CAREERS IN BIOLOGY

Genetic Counselor

Are you fascinated by how you inherit traits from your parents? If so, you could become a genetic counselor and help people assess their risk of inheriting or passing on genetic disorders.

Skills for the Job

Genetic counselors are medical professionals who work on a health care team. They analyze families' medical histories to determine the parents' risk of having children with genetic disorders, such as hemophilia or cystic fibrosis. Counselors also educate the public and help families with genetic disorders find support and treatment. These counselors may work in a medical center, a private practice, research, or a commercial laboratory. To become a counselor, you must earn a two-year master's degree in medical genetics and pass a test to become certified. The most important requirement is the ability to listen and to help families make difficult decisions.

For more careers in related fields, visit ca.bdol.glencoe.com/careers

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Cancer results from gene mutations. For example, ultraviolet radiation in sunlight can change the DNA in skin cells. The cells reproduce rapidly, causing skin cancer.

Reading Check **Explain** how mutations in body cells cause damage.

The effects of point mutations

Consider what might happen if an incorrect amino acid were inserted into a growing protein chain during the process of translation. The mistake might affect the structure of the entire molecule. Such a problem can occur if a point mutation arises. A **point mutation** is a change in a single base pair in DNA.

A simple analogy can illustrate point mutations. Read the following two sentences. Notice what happens when a single letter in the first sentence is changed.

THE DOG BIT THE CAT.
THE DOG BIT THE CAR.

As you can see, changing a single letter changes the meaning of the above sentence. Similarly, a change in a single nitrogenous base can change the entire structure of a protein because a change in a single amino acid can affect the shape of the protein. ***Figure 11.11A*** shows what can happen with a point mutation.

Frameshift mutations

When the ribosome moves along the mRNA strand, a new amino acid is added to the protein for every codon on the mRNA strand. What would happen if a single base were lost from a DNA strand?

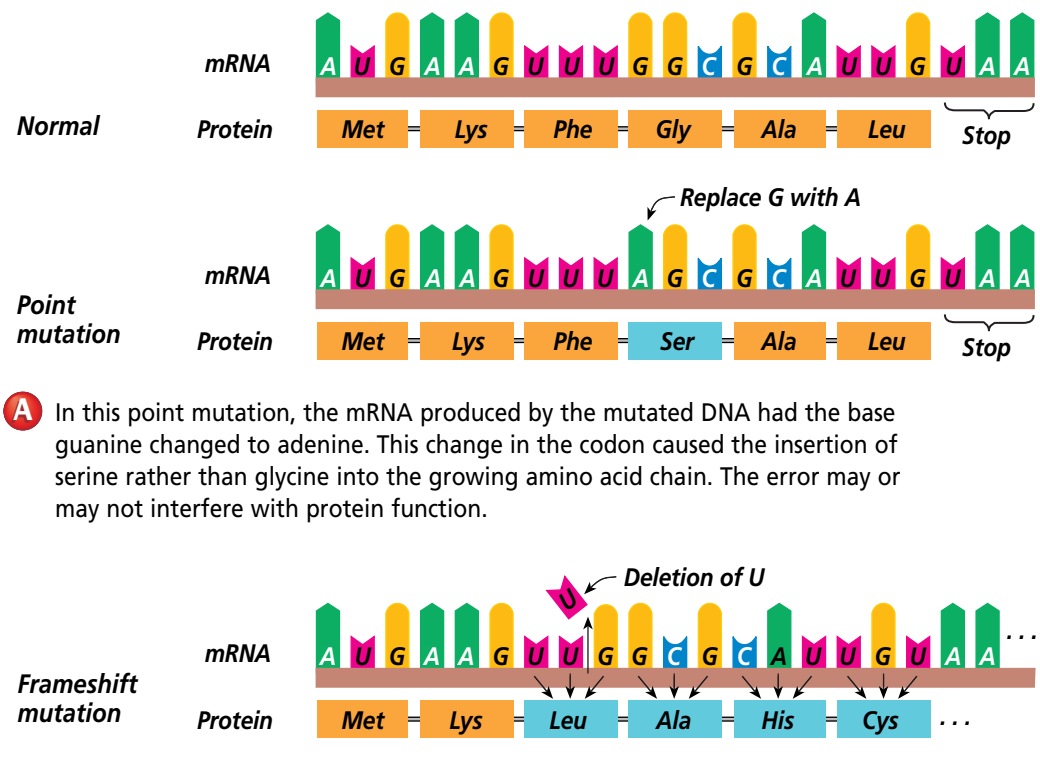

Figure 11.11
The results of a point mutation and a frameshift mutation are different. The diagrams show the mRNA and protein that would be formed from each corresponding DNA.
Infer ***Which type of mutation is likely to cause greater genetic damage?***

A In this point mutation, the mRNA produced by the mutated DNA had the base guanine changed to adenine. This change in the codon caused the insertion of serine rather than glycine into the growing amino acid chain. The error may or may not interfere with protein function.

B Proteins that are produced as a result of frameshift mutations seldom function properly because such mutations usually change many amino acids. Adding or deleting one base of a DNA molecule will change nearly every amino acid in the protein after the addition or deletion.

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This new sequence with the deleted base would be transcribed into mRNA. But then, the mRNA would be out of position by one base. As a result, every codon after the deleted base would be different, as shown in ***Figure 11.11B.*** This mutation would cause nearly every amino acid in the protein after the deletion to be changed. In the sentence THE DOG BIT THE CAT, deleting a G would produce the sentence THE DOB ITT HEC AT. The same effect would result from the addition of a single base. A mutation in which a single base is added to or deleted from DNA is called a **frameshift mutation** because it shifts the reading of codons by one base. In general, point mutations are less harmful to an organism because they disrupt only a single codon. The *MiniLab* on the next page will help you distinguish point mutations from frameshift mutations, and the *Problem-Solving Lab* on this page will show you an example of a common mutation in humans.

Reading Check **Compare and contrast** the cause and effect of a point mutation and a frameshift mutation.

Problem-Solving Lab 11.3

Make and Use Tables

What type of mutation results in sickle-cell anemia?

A disorder called sickle-cell anemia results from a genetic change in the base sequence of DNA. Red blood cells in patients with sickle-cell anemia have molecules of hemoglobin that are misshapen. As a result of this change in protein shape, sickled blood cells clog capillaries and prevent normal flow of blood to body tissues, causing severe pain.

Solve the Problem

The table below shows the sequence of bases in a short segment of the DNA that controls the order of amino acids in the protein hemoglobin.

DNA Base Sequences	
Normal hemoglobin	GGG CTT CTT TTT
Sickled hemoglobin	GGG CAT CTT TTT

Thinking Critically

1. **Interpret Data** Use ***Table 11.1*** on page 292 to transcribe and translate the DNA base sequence for normal hemoglobin and for sickled hemoglobin into amino acids. Remember that the table lists mRNA codons, not DNA base sequences.
2. **Define Operationally** Does this genetic change illustrate a point mutation or frameshift mutation? Explain your answer.
3. **Explain** Why is the correct sequence of DNA bases important to the production of proteins?
4. **Analyze** Assume that the base sequence reads GGG CTT CTT AAA instead of the normal sequence for hemoglobin. Would this result in sickled hemoglobin? Explain.

Chromosomal Alterations

Changes may occur in chromosomes as well as in genes. Alterations to chromosomes may occur in a variety of ways. For example, sometimes parts of chromosomes are broken off and lost during mitosis or meiosis. Often, chromosomes break and then rejoin incorrectly. Sometimes, the parts join backwards or even join to the wrong chromosome. These structural changes in chromosomes are called **chromosomal mutations.**

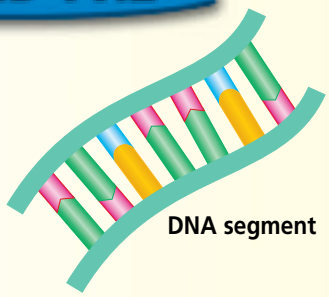
Chromosomal mutations occur in all living organisms, but they are especially common in plants. Such mutations affect the distribution of genes to the gametes during meiosis. Homologous chromosomes do not pair correctly when one chromosome has extra or missing parts, so separation of the homologous chromosomes does not occur normally. Gametes that should have a complete set of genes may end up with extra copies or a complete lack of some genes.

MiniLab 11.2

Make and Use Tables

Gene Mutations and Proteins

Gene mutations often have serious effects on proteins. In this activity, you will demonstrate how such mutations affect protein synthesis.



Procedure

1. Copy the following base sequence of one strand of an imaginary DNA molecule: AATGCCAGTGGTTCGCAC.
2. Then, write the base sequence for an mRNA strand that would be transcribed from the given DNA sequence.
3. Use ***Table 11.1*** to determine the sequence of amino acids in the resulting protein fragment.
4. If the fourth base in the original DNA strand were changed from G to C, how would this affect the resulting protein fragment?
5. If a G were added to the original DNA strand after the third base, what would the resulting mRNA look like? How would this addition affect the protein?

Analysis

1. **Define Operationally** Which change in DNA was a point mutation? Which was a frameshift mutation?
2. **Infer** How did the point mutation affect the protein?
3. **Analyze** How did the frameshift mutation affect the protein?

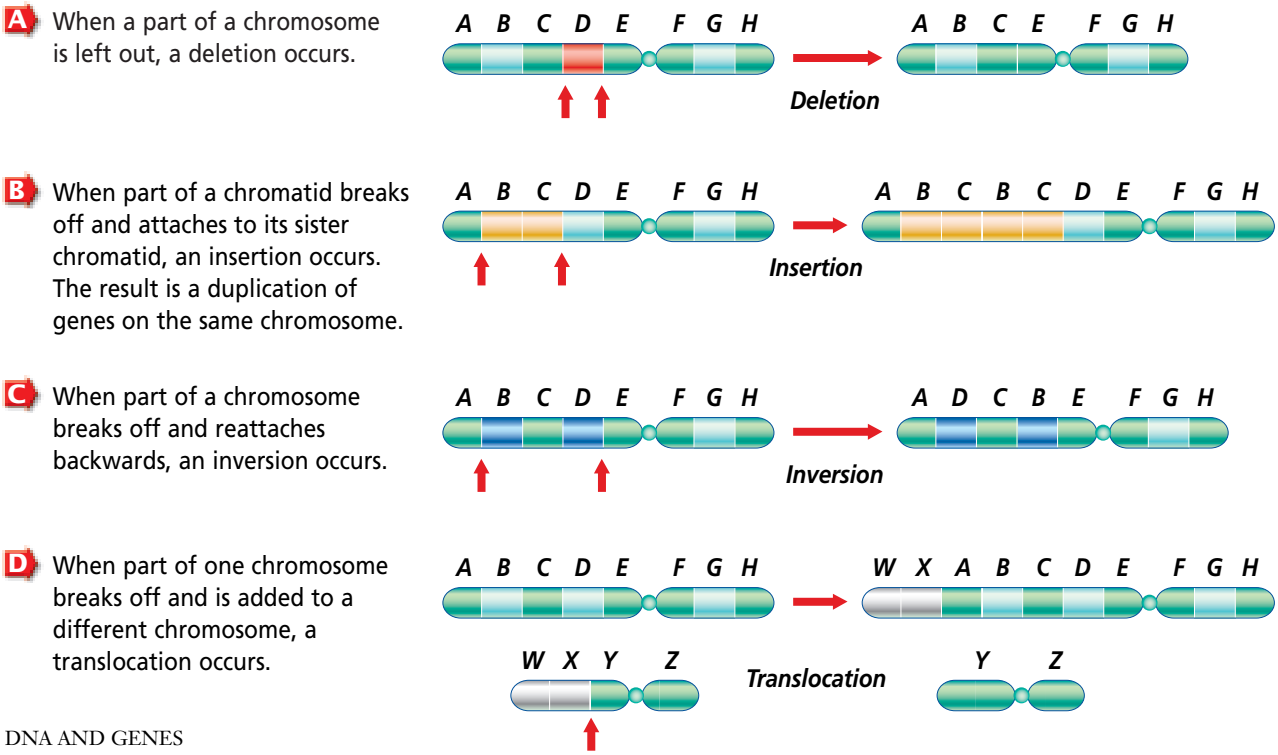
Few chromosomal mutations are passed on to the next generation because the zygote usually dies. In cases where the zygote lives and develops, the mature organism is often sterile and thus incapable of producing offspring. The most important of these mutations—deletions, insertions, inversions, and translocations—are illustrated in ***Figure 11.12.***

Causes of Mutations

Some mutations seem to just happen, perhaps as a mistake in base pairing during DNA replication. These mutations are said to be spontaneous. However, many mutations are caused by factors in the environment. Any agent that can cause a change in DNA is called a **mutagen** (MYEW tuh jun). Mutagens include radiation, chemicals, and even high temperatures.

Forms of radiation, such as X rays, cosmic rays, ultraviolet light, and

Figure 11.12
Study the four kinds of chromosomal mutations.



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nuclear radiation, are dangerous mutagens because the energy they contain can damage or break apart DNA. The breaking and reforming of a double-stranded DNA molecule can result in deletions. Some kinds of radiation can convert a base into a different, incorrect base or fuse two bases together.

Chemical mutagens include dioxins, asbestos, benzene, and formaldehyde, substances that are commonly found in buildings and in the environment, ***Figure 11.13.*** These mutagens are highly reactive substances that interact with the DNA molecule and cause changes. Chemical mutagens usually cause substitution mutations.

Repairing DNA

The cell processes that copy genetic material and pass it from one generation to the next are usually accurate. This accuracy is important to ensure the genetic continuity of both new cells and offspring. Yet, mistakes sometimes do occur. There are many sources of mutagens in an organism's environment. Although many of these are due to human activities, others—such as cosmic rays from outer space—have affected living things since the beginning of life. Repair mechanisms that fix mutations in cells have evolved. Much like a book editor, enzymes proofread the DNA and replace incorrect nucleotides with correct nucleotides. These repair mechanisms work extremely well, but they are not perfect. The greater the exposure to a mutagen such as UV light, the more likely is the chance that a mistake will not be corrected. Thus, it is wise for people to limit their exposure to mutagens.

Figure 11.13
Asbestos was formerly used to insulate buildings. It is now known to cause lung cancer and other lung diseases and must be removed from buildings, as these workers are doing.

Section Assessment

Understanding Main Ideas

1. What is a mutation?
2. Describe how point mutations and frameshift mutations affect the synthesis of proteins.
3. Explain why a mutation in a sperm or egg cell has different consequences than one in a heart cell.
4. How are mutations and cancer related?

Thinking Critically

5. The chemicals in cigarette smoke are known to cause cancer. Propose a series of steps that could lead to development of lung cancer in a smoker.

Skill Review

6. **Recognize Cause and Effect** In an experiment with rats, the treatment group is exposed to radiation while the control group is not. Months later, the treatment group has a greater percentage of rats with cancer and more newborn rats with birth defects than the control group. Explain how the exposure to radiation may have affected the treatment group's DNA. Infer how these effects could have caused cancer and birth defects. For more help, refer to *Recognize Cause and Effect* in the **Skill Handbook.**

INVESTIGATE

BioLab

RNA Transcription

Before You Begin

Although DNA remains in the nucleus of a cell, it passes its information into the cytoplasm by way of another nucleic acid, messenger RNA. The base sequence of this mRNA is complementary to the sequence in the strand of DNA. It is produced by base pairing during transcription. In this activity, you will demonstrate the process of transcription through the use of paper DNA and mRNA models.

PREPARATION

Problem

How does the order of bases in DNA determine the order of bases in mRNA?

Objectives

In this BioLab, you will:

- **Formulate a model** to show how the order of bases in DNA determines the order of bases in mRNA.
- **Infer** why the structure of DNA enables it to be easily transcribed.

Materials

construction paper, 5 colors
scissors
clear tape

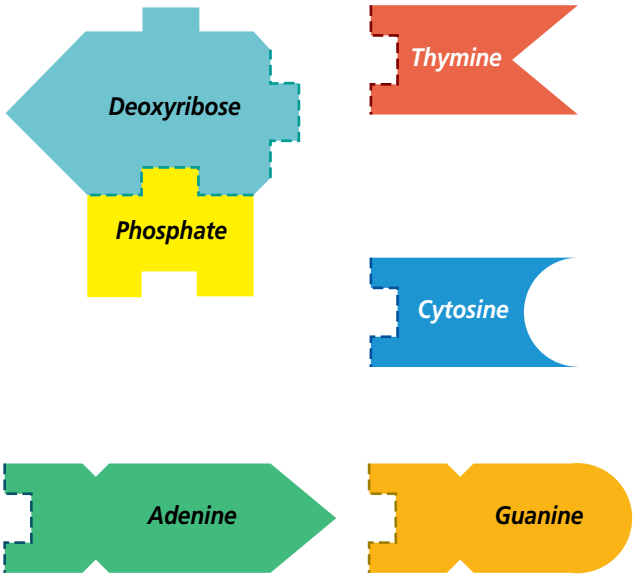
Safety Precautions

CAUTION: ***Be careful when using scissors. Always use goggles in the lab.***

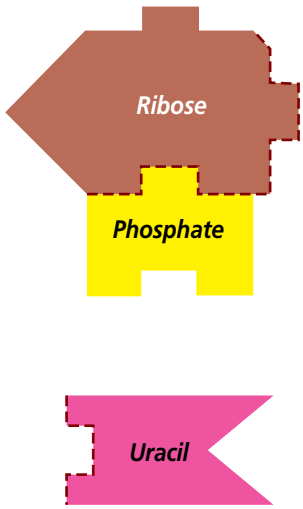
Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

Parts for DNA Nucleotides



Extra Parts for RNA Nucleotides



Procedure

1. Copy the parts for the four different DNA nucleotides onto your construction paper, making sure that each different nucleotide is on a different color paper. Make ten copies of each nucleotide.
2. Using scissors, carefully cut out the shapes of each nucleotide.
3. Using any order of nucleotides that you wish, construct a double-stranded DNA molecule. If you need more nucleotides, copy them as in step 1.
4. Fasten your molecule together using clear tape. Do not tape across base pairs.
5. As in step 1, copy the parts for A, G, and C RNA nucleotides. Use the same colors of construction paper as in step 1. Use the fifth color of construction paper to make copies of uracil nucleotides.
6. With scissors, carefully cut out the RNA nucleotide shapes.
7. With your DNA molecule in front of you, demonstrate the process of transcription by first pulling the DNA molecule apart between the base pairs.
8. Using only one of the strands of DNA, begin matching complementary RNA nucleotides with the exposed bases on the DNA model to make mRNA.
9. When you are finished, tape your new mRNA molecule together.

Matt Meadows

Analyze and Conclude

1. **Observe and Infer** Does the mRNA model more closely resemble the DNA strand from which it was transcribed or the complementary strand that wasn't used? Explain your answer.
2. **Recognize Cause and Effect** Explain how the structure of DNA enables the molecule to be easily transcribed. Why is this important for genetic information?
3. **Relate Concepts** Why is RNA important to the cell? How does an mRNA molecule carry information from DNA? Where does the mRNA molecule take the information?

Apply Your Skill

Research Do research to find out more about how the bases in DNA were identified and how the base pairing pattern was determined.

Web Links To find out more about DNA, visit ca.bdol.glencoe.com/DNA

BIO TECHNOLOGY

Scanning Probe Microscopes

Have you ever heard of someone dissecting a chromosome to get a closer look at DNA? Imagine an instrument small enough to allow you to grab hold of one of the nucleotides in a strand of DNA, yet powerful enough to provide a detailed image.

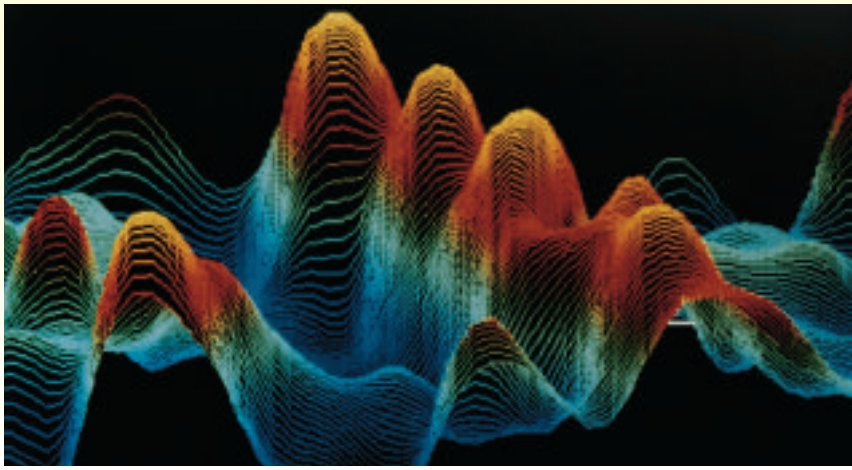
Scanning probe microscopes can show the arrangement of atoms on the surface of a molecule. They make it possible for scientists to pick up molecules, and even atoms, and move them around. They can also be used to observe how biological molecules interact. There are many types of scanning probe microscopes. All of them use a very sharp probe that may be only a single atom wide at its tip. The probe sits very close to the specimen but does not actually touch it. As the probe moves across, or scans, the specimen, it measures some property of the specimen.

The scanning tunneling microscope (STM) The STM uses a probe through which a tiny amount of electric current flows. As the probe scans a molecule, it encounters ridges and valleys formed by the different kinds of atoms on the molecule's surface. The probe moves up and down as needed to keep the current constant. The movements of the probe are recorded by a computer, which produces an image of the molecule.

The atomic force microscope (AFM) The AFM can measure many different properties, including electricity, magnetism, and heat. As the probe moves across the specimen, changes in the property being measured move the probe. These changes are used to create the image.

What can they do? One of the primary advantages of scanning probe microscopy, besides its atomic-level resolution, is the ability to observe molecules in air or liquid. This means that biologists can "watch" molecules interact as they would inside a cell.

Magnification: unavailable



STM image of DNA

Scanning probe microscopes are being used to study patterns in liquid crystals, wave convection, molecular surfaces of materials and molecular events such as the function of bacterial toxins and ion channels, actin and myosin interactions in muscle cells, and protein folding.

Imaging transcription Biologists currently are imaging factors that are involved in the transcription of DNA. These factors include enzymes that cut DNA and those that repair DNA errors. By using the AFM, biologists are beginning to identify the DNA binding sites for these enzymes, which will be used in mapping studies of DNA. This will allow further understanding of the process of transcription.

Applying Biotechnology

Think Critically What advantages do scanning probe microscopes have over other types of microscopes? Predict some future applications that would make use of these advantages.

To find out more about microscopes, visit ca.bdol.glencoe.com/biotechnology

Photo Researchers

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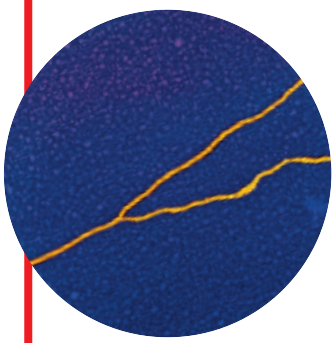
Chapter 11 Assessment

Study Guide

Section 11.1

DNA: The Molecule of Heredity



Color-enhanced TEM
Magnification: 75 000×

Key Concepts

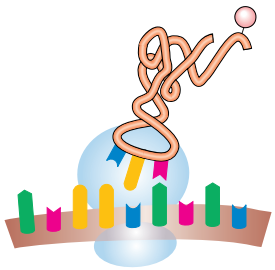
- Alfred Hershey and Martha Chase demonstrated that DNA is the genetic material.
- DNA, the genetic material of organisms, is composed of four kinds of nucleotides. A DNA molecule consists of two strands of nucleotides with sugars and phosphates on the outside and bases paired by hydrogen bonding on the inside. The paired strands form a twisted-zipper shape called a double helix.
- Because adenine can pair only with thymine, and guanine can pair only with cytosine, DNA can replicate itself with great accuracy.

Vocabulary

DNA replication (p. 284)
double helix (p. 283)
nitrogenous base (p. 282)

Section 11.2

From DNA to Protein



Key Concepts

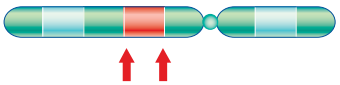
- Genes are small sections of DNA. Most sequences of three bases in the DNA of a gene code for a single amino acid in a protein.
- Messenger RNA is made in a process called transcription. The order of nucleotides in DNA determines the order of nucleotides in messenger RNA.
- Translation is a process through which the order of bases in messenger RNA codes for the order of amino acids in a protein.

Vocabulary

codon (p. 292)
messenger RNA (p. 289)
ribosomal RNA (p. 290)
transcription (p. 290)
transfer RNA (p. 290)
translation (p. 293)

Section 11.3

Genetic Changes



Key Concepts

- A mutation is a change in the base sequence of DNA. Mutations may affect only one gene, or they may affect whole chromosomes.
- Mutations in eggs or sperm affect future generations by producing offspring with new characteristics. Mutations in body cells affect only the individual and may result in cancer.

Vocabulary

chromosomal mutation (p. 299)
frameshift mutation (p. 299)
mutagen (p. 300)
mutation (p. 296)
point mutation (p. 298)

FOLDABLES Study Organizer To help you review DNA, use the Organizational Study Fold on page 288.

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Chapter 11 Assessment

Vocabulary Review

Review the Chapter 11 vocabulary words listed in the Study Guide on page 305. Distinguish between the vocabulary words in each pair below.

1. transcription—translation
2. point mutation—frameshift mutation
3. transfer RNA—messenger RNA
4. mutation—mutagen
5. nitrogenous base—codon

Understanding Key Concepts

6. Which of the following processes requires prior DNA replication?
   A. transcription **C.** mitosis
   B. translation **D.** protein synthesis
7. In which of the following processes does the DNA unzip?
   A. transcription and translation
   B. transcription and replication
   C. replication and translation
   D. mutation
8. Which DNA strand can base pair with the DNA strand shown at the right?

   A. T-A-C-G-A-T **C.** U-A-C-G-A-U
   B. A-T-G-C-T-A **D.** A-U-G-C-U-A
9. Which of the following nucleotide chains could be part of a molecule of RNA?
   A. A-T-G-C-C-A **C.** G-C-C-T-T-G
   B. A-A-T-A-A-A **D.** A-U-G-C-C-A
10. Which of the following mRNA codons would cause synthesis of a protein to terminate? Refer to ***Table 11.1.***
    A. GGG **C.** UAG
    B. UAC **D.** AAG
11. The genetic code for an oak tree is _____.
    A. more similar to an ash tree than to a squirrel
    B. more similar to a chipmunk than to a maple tree
    C. more similar to a mosquito than to an elm tree
    D. exactly the same as for an octopus
12. A deer is born normal, but UV rays cause a mutation in its retina. Which of the following statements is *least* likely to be true?
    A. The mutation may be passed on to the offspring of the deer.
    B. The mutation may cause retinal cancer.
    C. The mutation may interfere with the function of the retinal cell.
    D. The mutation may interfere with the structure of the retinal cell.
13. Chemical Q causes the change in the sequence of nucleotides shown below. This change is an example of a(n) _____.
    A. point mutation
    B. frameshift mutation
    C. translocation
    D. inversion

Constructed Response

14. **Open Ended** Explain why a mutation in a lung cell would not be passed on to offspring.
15. **Open Ended** Write the sequence for a segment of DNA that codes for the following chain of amino acids: valine-serine-proline-glycine-leucine. Compare your DNA sequence with another student's sequence. Why are they likely to be different?
16. **Open Ended** Would the amount of cytosine and guanine be equal to each other in an RNA molecule? Explain your answer.

Thinking Critically

17. **Make Inferences** Explain how the universality of the genetic code is evidence that all organisms alive today may have evolved from a common ancestor in the past.

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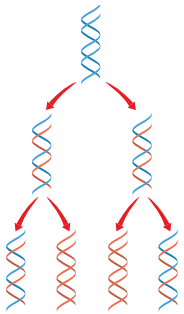
CONTENTS

Chapter 11 Assessment

18. Summarize Using the diagram to the right, describe the way DNA replicates. Refer to the red and blue strands in your answer.



19. REAL WORLD BIOCHALLENGE Cystic fibrosis is an inherited genetic disorder that affects about 1 in 3900 live births of all Americans. Visit ca.bdol.glencoe.com to find out what type of changes in DNA cause this disorder. How are these changes reflected in the symptoms of the disorder?

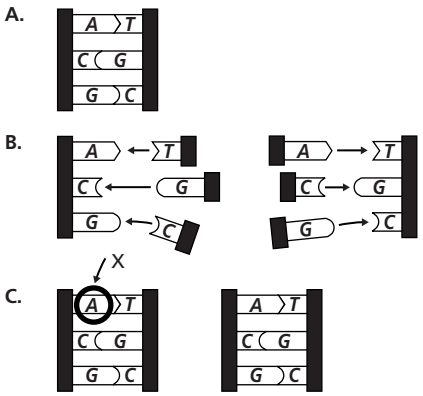
California Standards Practice

The assessed California standard appears next to the question.

All questions aligned and verified by The Princeton Review

Part 1 Multiple Choice

Use the diagram to answer questions 20–22.

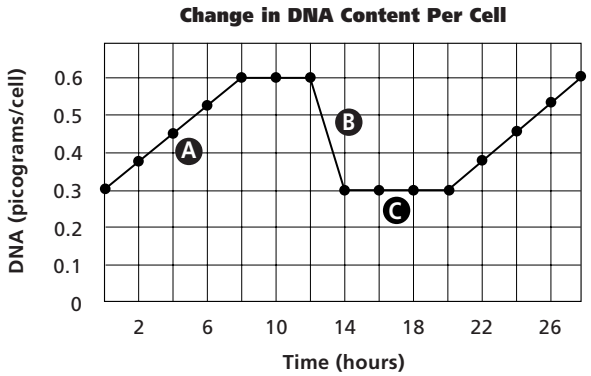


20. What process is shown in diagrams A–C?
5b **A.** transcription **C.** translocation
B. translation **D.** replication

21. What occurred between diagrams A and B?
5b **A.** DNA was copied.
B. DNA was translated.
C. DNA was unzipped.
D. DNA mutated.

22. What structure is represented by the circle
5a marked "X"?
A. nitrogenous base **C.** nucleotide
B. deoxyribose **D.** phosphate group

The following graph records the amount of DNA in liver cells that have been grown in a culture so that all the cells are at the same phase in the cell cycle. Study the graph and answer questions 23 and 24.



23. What process are the cells undergoing at
5b part A of the graph to cause the observed change in DNA content?
A. transcription
B. translation
C. DNA replication
D. meiosis

24. During what part of the graph is translation most likely to occur?
A. at part A
B. at part B
C. at part C
D. at both part A and part C

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

25. Open Ended A point mutation that doesn't change the amino acid sequence of a protein is known
4c as a silent mutation. Explain why a silent mutation might not affect the protein for which it codes.