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 birth defects, 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.

Reading Biology

Scan the vocabulary words listed in the Section Preview at the start of each section. Note familiar words. Make a list of current events issues you may have heard about that involve genetics, DNA, or cloning. As you read the chapter, refer back to your list to add notes from the material.

BIOLOGY Online

To find out more about DNA and genes, visit the Glencoe Science Web site.
science.glencoe.com

The appearance of these two flies depends on the type of genes they contain. Chromosomes, made of genes, which are made of DNA, determine how an organism looks and how it functions.

Section

11.1 DNA: The Molecule of Heredity

SECTION PREVIEW

Objectives

Analyze the structure of DNA.

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

Vocabulary

nitrogen base
double helix
DNA replication

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 substance DNA, contained in genes, holds this information. Because of the unique structure of DNA, new copies of the information can be easily reproduced.

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 producing 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.

The structure of DNA

DNA is capable of holding all this 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 nitrogen base. The simple sugar in DNA, called

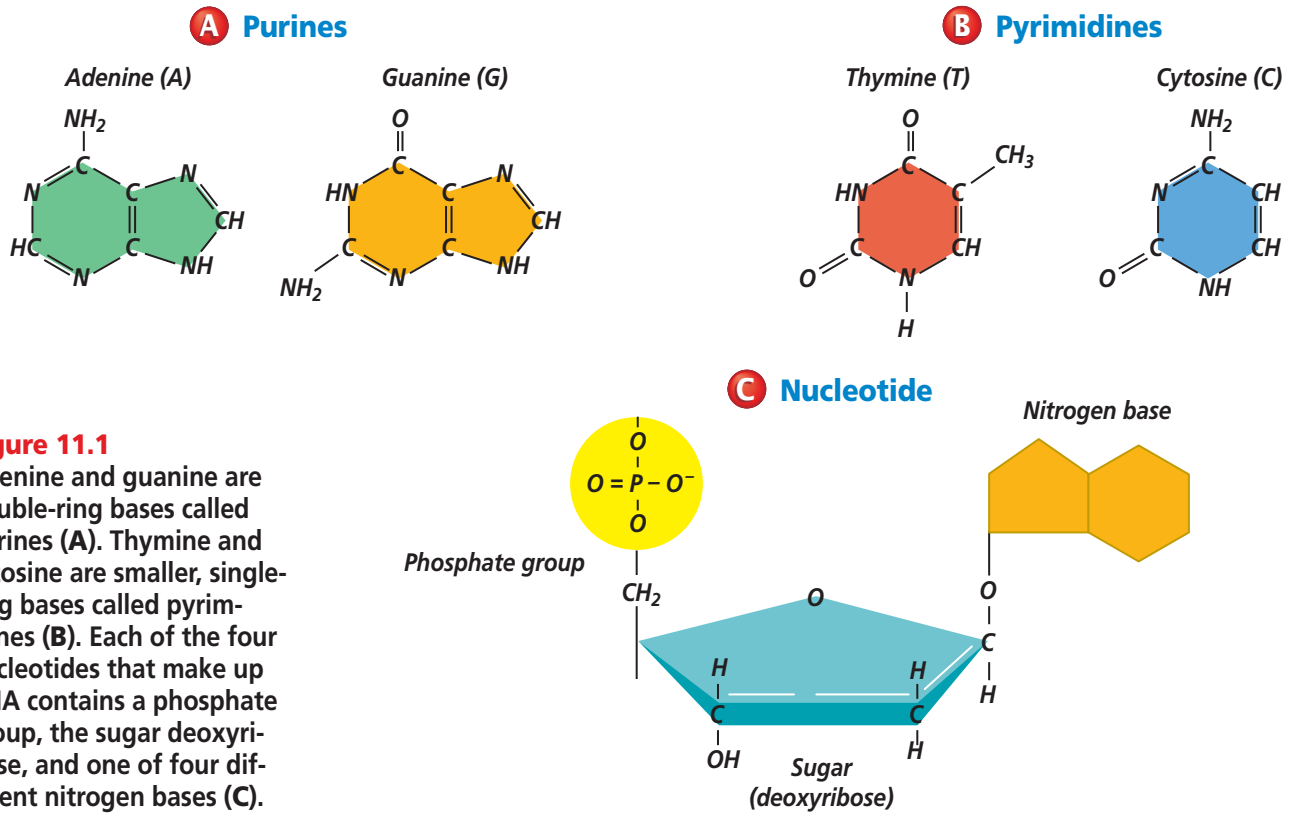

Figure 11.1
Adenine and guanine are double-ring bases called purines (A). Thymine and cytosine are smaller, single-ring bases called pyrimidines (B). Each of the four nucleotides that make up DNA contains a phosphate group, the sugar deoxyribose, and one of four different nitrogen bases (C).

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 **nitrogen base** is a carbon ring structure that contains one or more atoms of nitrogen. In DNA, there are four possible nitrogen 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 nitrogen bases stick out like teeth on 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.

In 1953, James Watson and Francis Crick published a journal article that was only one page in length, yet monumental in importance. Watson and Crick proposed that DNA is made of two chains of nucleotides joined together by the nitrogen bases. Just as the teeth of a zipper hold the two sides of the zipper together, the nitrogen bases of the nucleotides hold the two strands of DNA together with weak hydrogen bonds. The two strands can be held together in this way because they are complementary to each other; that is, the bases on one strand determine the bases on the other strand. Specifically, adenine on one strand bonds with a thymine on the other strand, and guanine on one strand bonds with a cytosine on the other strand. These two bonded bases, called a complementary base pair, explain why adenine and

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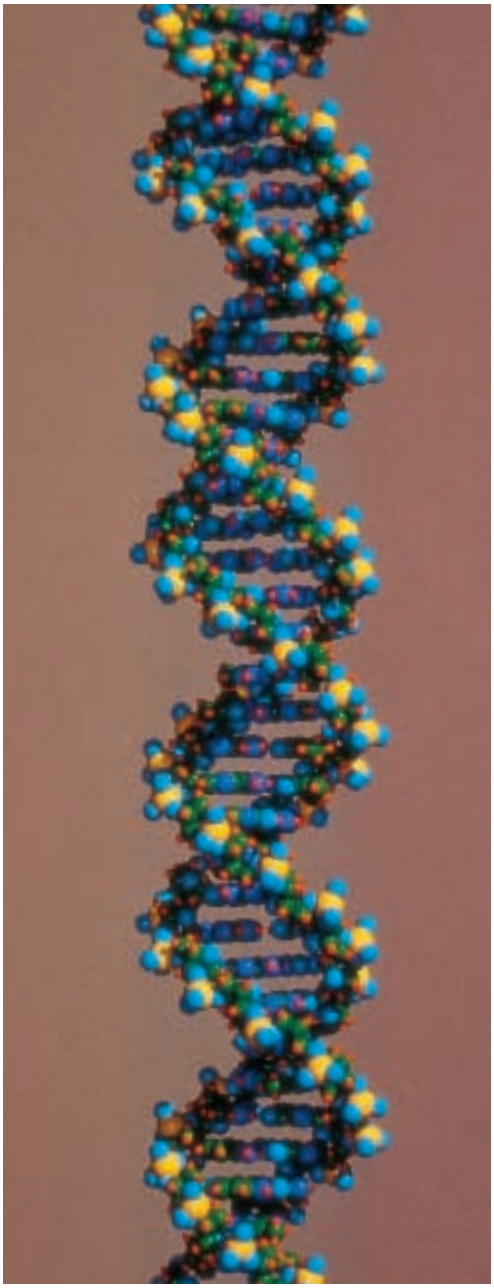
thymine are always present in equal amounts. Likewise, the guanine and cytosine base pairs result in equal amounts of these nucleotides in DNA. Watson and Crick also proposed that DNA is shaped like a long zipper that is twisted. When something is twisted like a coiled spring, the shape is called a helix. Because DNA is composed of two strands twisted together, its shape is called a **double helix.** This shape is shown in ***Figure 11.2.***



Problem-Solving Lab 11-1 — Interpreting 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 these experiments provide evidence of a relationship among the nitrogen bases of DNA.

Analysis

Examine ***Table 11.1.*** Compare the amounts of adenine, guanine, cytosine, and thymine found in the DNA of each of the cells studied.

Table 11.1 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 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. How do the relative amounts of each base in herring sperm compare with the relative amounts of each base in yeast?
3. What fact can you state about the overall composition of DNA, regardless of its source?

The importance of nucleotide sequences

An elm, an elk, and an eel 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 nucleotides with adenine, thymine, guanine, and cytosine bases. How can organisms be so different from each other if their genetic material is made of the same four nucleotides? Their differences result

Word Origin

helix
From the Latin word *helix*, meaning "spiral." A double helix has two twisted strands that form a spiral.

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

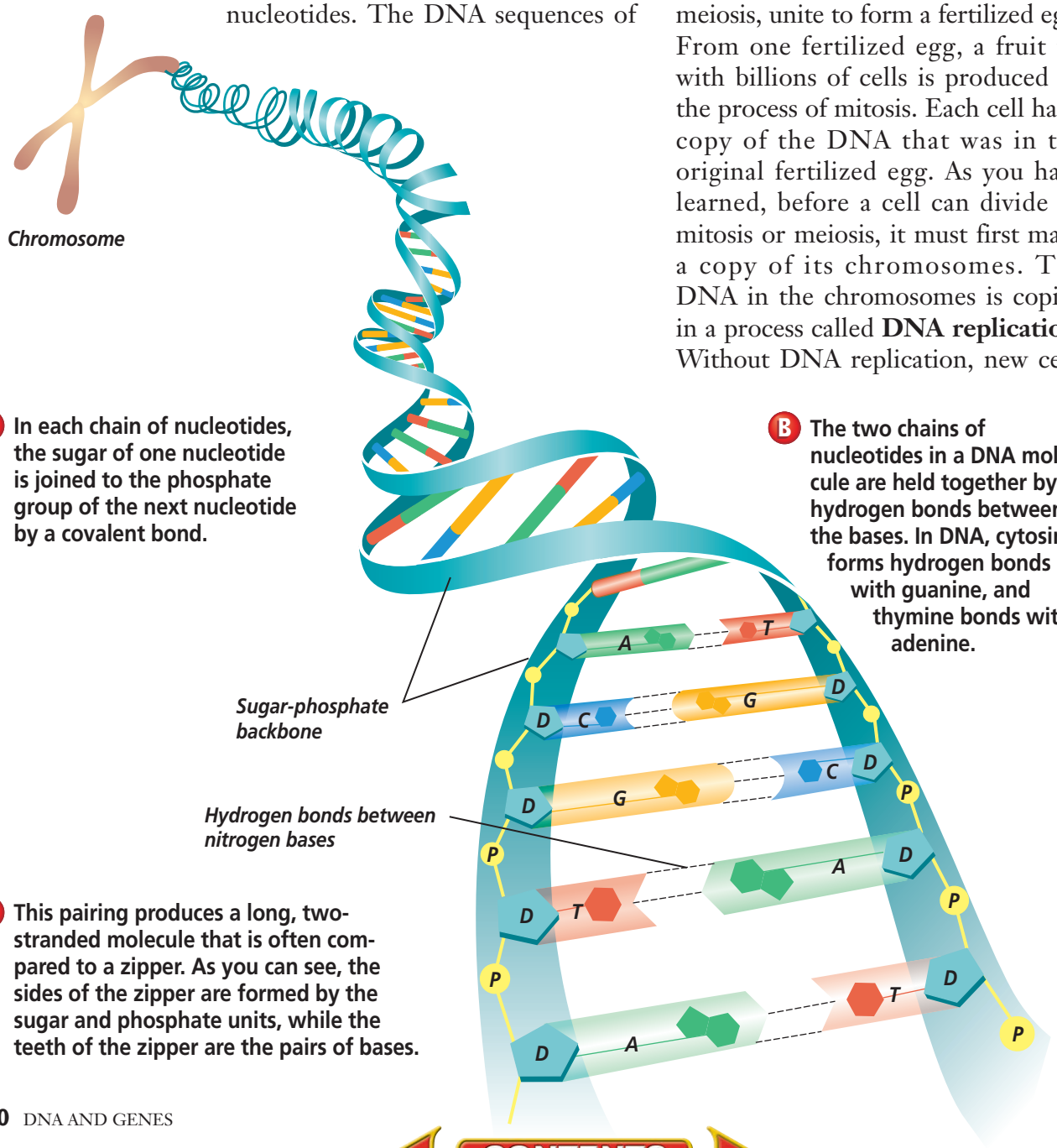
from the sequence of the four different nucleotides along the DNA strands, as you can see in ***Figure 11.3.***

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 between two organisms, the greater the similarity in their order of DNA nucleotides. The DNA sequences of a chimpanzee are similar to those of a gorilla, but different from those of a rose bush. Scientists use nucleotide sequences to determine evolutionary relationships among organisms. Nucleotide sequences can also be used to determine whether two people are related, or whether the DNA from a crime scene matches the DNA of a suspected criminal.

Replication of DNA

A sperm cell and an egg cell of a fruit fly, both produced through meiosis, unite to form a fertilized egg. From one fertilized egg, a fruit fly with billions 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

Figure 11.3
The structure of DNA is shown here.



A In each chain of nucleotides, the sugar of one nucleotide is joined to the phosphate group of the next nucleotide by a covalent bond.

B The two chains of nucleotides in a DNA molecule are held together by hydrogen bonds between the bases. In DNA, cytosine forms hydrogen bonds with guanine, and thymine bonds with adenine.

C This pairing produces a long, two-stranded molecule that is often compared to a zipper. As you can see, the sides of the zipper are formed by the sugar and phosphate units, while the teeth of the zipper are the pairs of bases.

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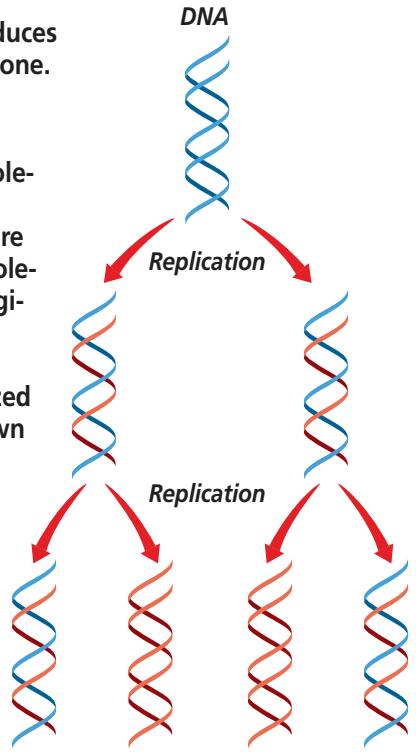
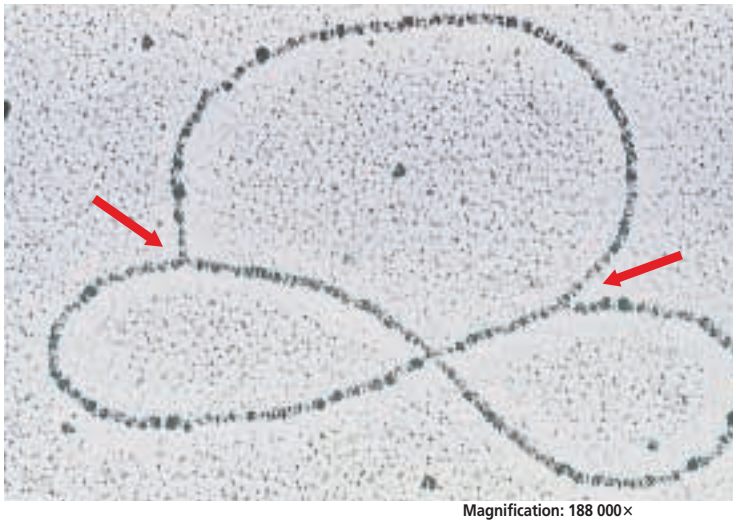
Figure 11.4
DNA replication produces two molecules from one.

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 circular bacterial DNA is replicating. The photo shows two loops. The bottom loop is twisted into a figure-8 shape. Replication is taking place at the intersections of the two loops, as indicated by the arrows.



Magnification: 188 000×

would have only half the DNA of their parents. Species could not survive, and 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 knew the order of bases on one strand, you could 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 to make a new DNA molecule. How can a molecule serve as a pattern? Read the *Inside Story* on the next page to find out.

DNA replication begins as an enzyme breaks the hydrogen bonds between nitrogen bases that hold the two strands together, thus unzipping the DNA molecule. As the DNA continues to unzip, nucleotides that are floating free in the surrounding medium bond to the single strands by base pairing. Another enzyme bonds these new 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.

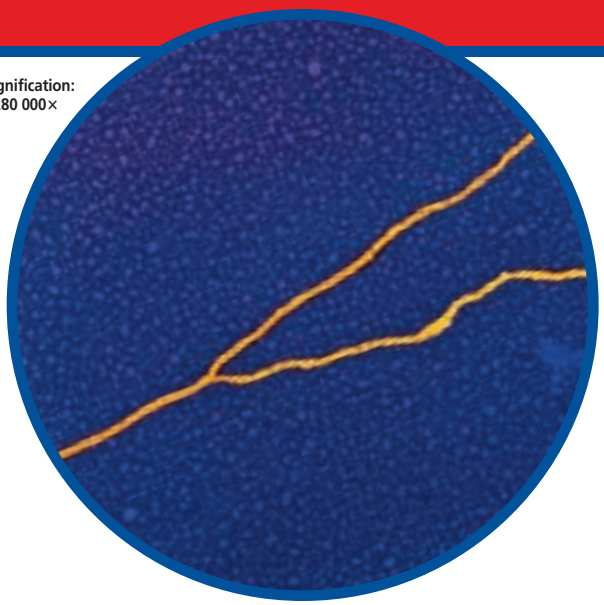
When all the DNA in all the chromosomes of the cell has been copied by replication, there are two copies of the organism's genetic information. In this way, the genetic makeup of an organism can be passed on to new cells during mitosis or to new generations through meiosis followed by sexual reproduction.

INSIDE STORY

Copying DNA

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 would be the outcome if mitosis occurred before replication took place?***



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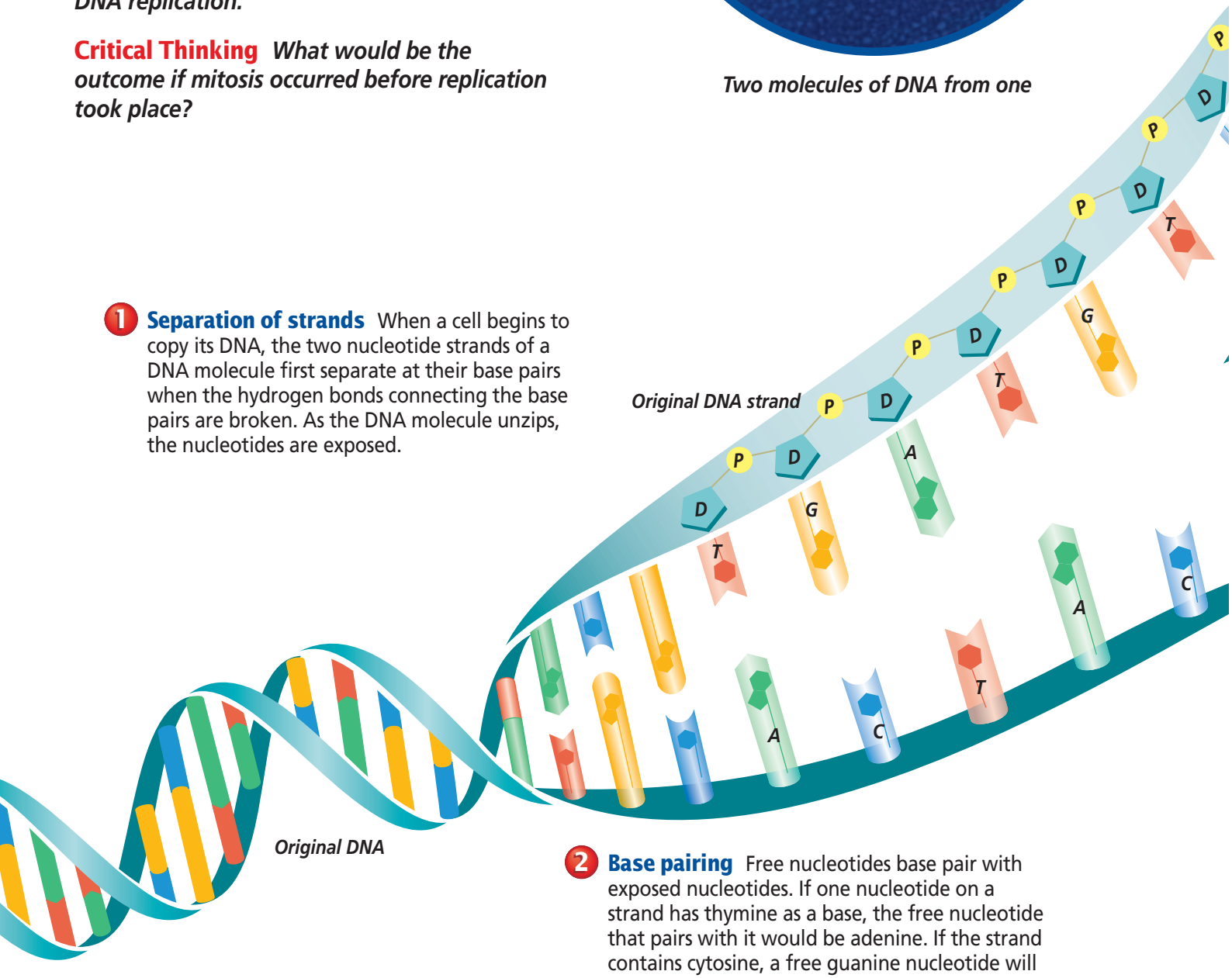
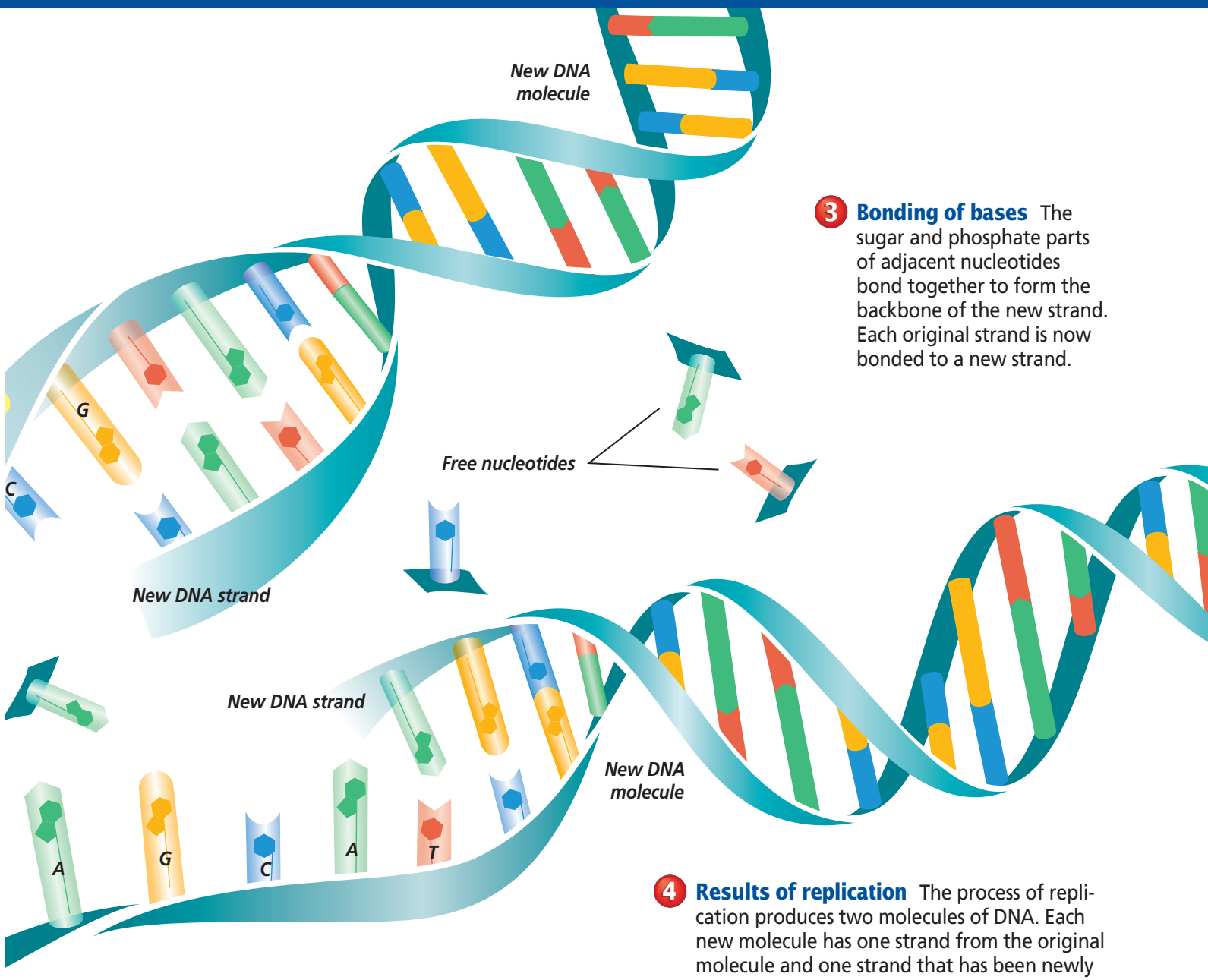
Two molecules of DNA from one



1 Separation of strands When a cell begins to copy its DNA, the two nucleotide strands of a DNA molecule first separate at their base pairs when the hydrogen bonds connecting the base pairs are broken. As the DNA molecule unzips, the nucleotides are exposed.

2 Base pairing Free nucleotides base pair with exposed nucleotides. If one nucleotide on a strand has thymine as a base, the free nucleotide that pairs with it would be adenine. If the strand contains cytosine, a free guanine nucleotide will pair with it. Thus, each strand builds its complement by base pairing with free nucleotides.



3 Bonding of bases The sugar and phosphate parts of adjacent nucleotides bond together to form the backbone of the new strand. Each original strand is now bonded to a new strand.

4 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 pair?
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 nitrogen bases on one strand of a DNA molecule is GGCAGTTCATGC. What would be the sequence of bases on the complementary strand?

Skill Review

6. **Sequencing** Sequence the steps that occur during DNA replication. For more help, refer to *Organizing Information* in the **Skill Handbook.**

SECTION PREVIEW

Objectives

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

Sequence the steps involved in protein synthesis.

Vocabulary

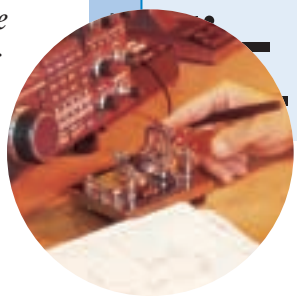
messenger RNA
ribosomal RNA
transfer RNA
transcription
codon
translation

Section

11.2 From DNA to Protein

Morse code was a method of communicating that was developed in the nineteenth century. This code used a pattern of dots and dashes to represent letters of the alphabet. In this way, long sequences of dots and dashes could produce an infinite number of different messages. Living organisms have their own code, called the genetic code, in which the sequence of nucleotides in DNA can be converted to the sequence of amino acids in proteins.

Sign	Signal	Sign	Signal
A	·–	S	···
B	–···	T	–
C	–·–·	U	··–
D	–··	V	···–
E	·	W	·––
F	··–·	X	–··–
G	––·	Y	–·––
H	····	Z	––··
I	··	1	·–––––
J	·–––	2	··–––
K	–·–	3	···––
L	·–··	4	····–
M	––	5	·····
		6	–····
		7	––···
		8	–––··
		9	––––·
		0	–––––



This sample of Morse code (above) is being sent (inset).

Genes and Proteins

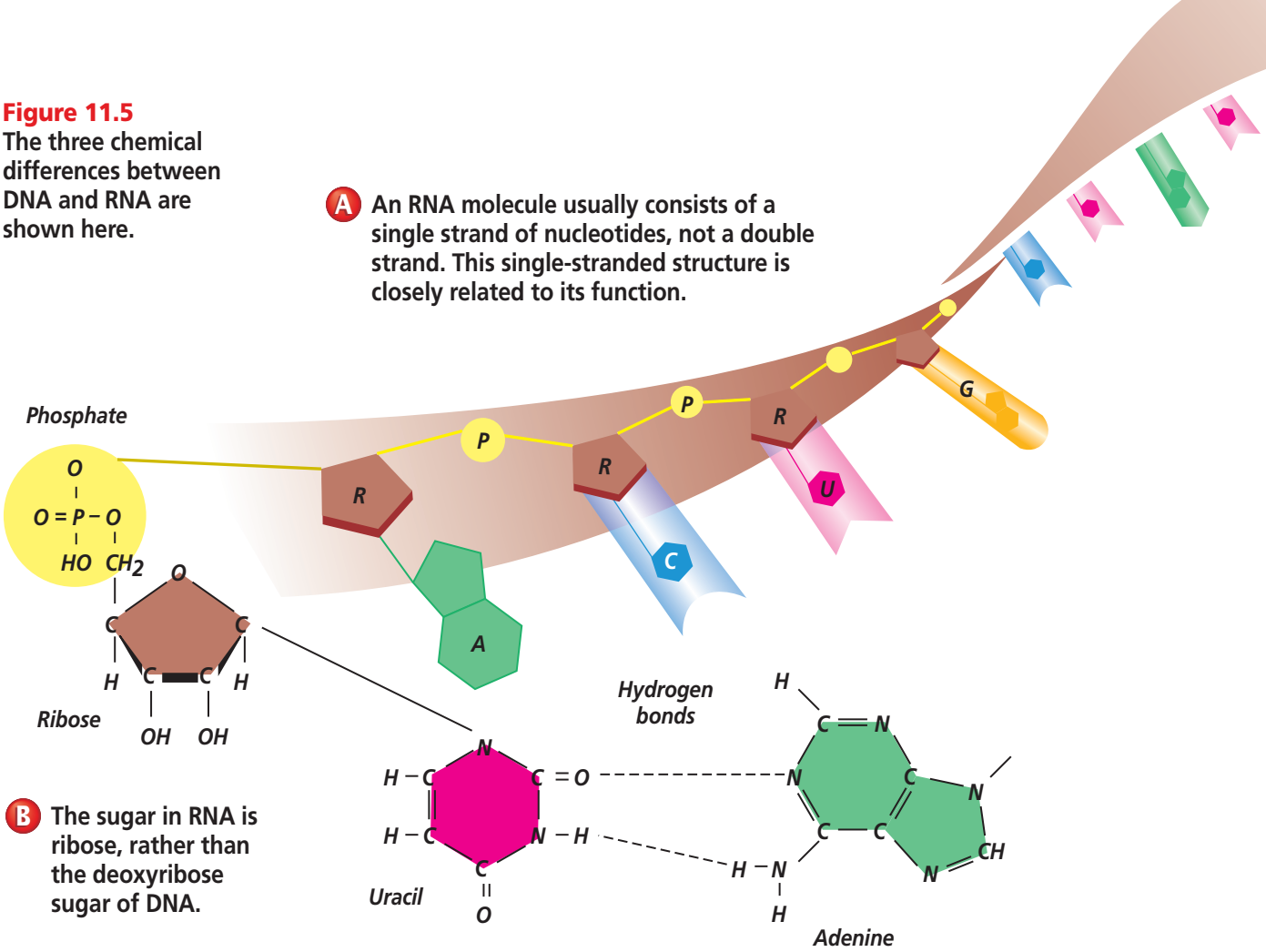
The sequences of nucleotides in DNA contain information. This information is put to work through the production of proteins. Proteins form into complex three-dimensional shapes to become key cell structures and regulators of cell functions. Some proteins become important structures, such as the filaments in muscle tissue, walls of blood vessels, and transport proteins in membranes. 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. It is estimated that each human cell contains about 80 000 genes.

RNA

RNA, like DNA, is a nucleic acid. However, RNA structure differs from DNA structure in three ways, shown in ***Figure 11.5***. First, RNA is single stranded—it looks like only one-half a zipper—whereas DNA is double stranded. The sugar in RNA is ribose; DNA has deoxyribose.

Figure 11.5
The three chemical differences between DNA and RNA are shown here.



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

What is the role of RNA in the cell? Let's look at an analogy. 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 the 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 the 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 to build proteins. Extending the car-making analogy, you can consider these RNA molecules to be the workers in the protein assembly line. One type of RNA, **messenger RNA** (mRNA) brings information from the DNA in the nucleus to the cell's factory floor, the cytoplasm. On the

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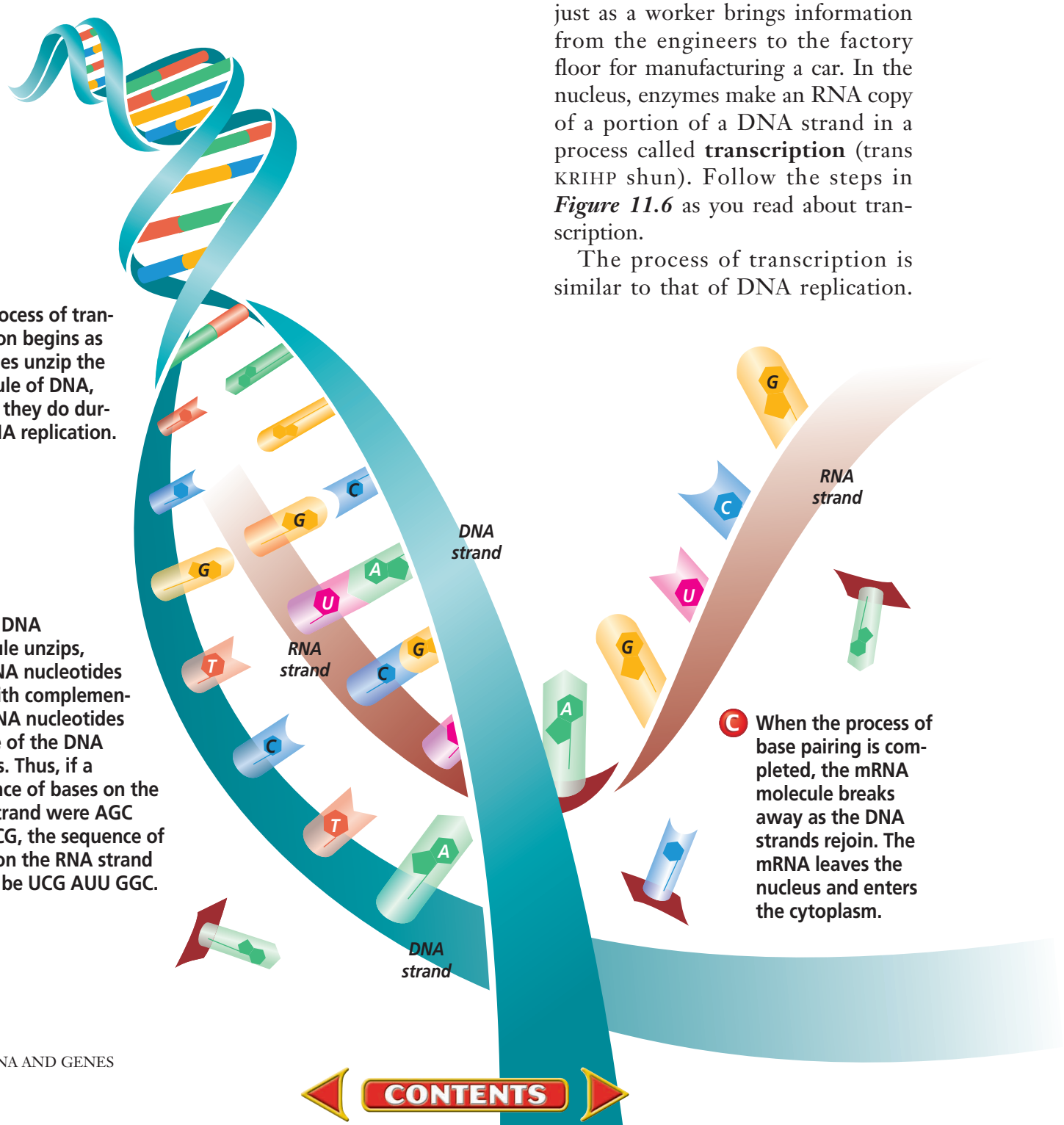
factory floor, the mRNA becomes part of the assembly line. Ribosomes, made of **ribosomal RNA** (rRNA), clamp onto the mRNA and use its information to assemble the amino acids in the correct order. The third type of RNA, **transfer RNA** (tRNA) is the supplier. Transfer RNA transports amino acids to 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 from the DNA to the cell's ribosomes for manufacturing proteins, just as a worker brings information from the engineers to the factory floor 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 11.6*** as you read about transcription.

The process of transcription is similar to that of DNA replication.

Figure 11.6
Messenger RNA is made during the process of transcription.



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The main difference is that transcription results in the formation of one single-stranded RNA molecule rather than a double-stranded DNA molecule. You can find out how scientists use new microscopes to "watch" transcription take place by reading the *BioTechnology* at the end of the chapter. Modeling the process of transcription in the *BioLab* will help you to understand this process.

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 nitrogen bases as its alphabet. As you know, proteins are built from chains of smaller molecules called 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 different amino acids, but mRNA contains only four types of bases. How can these bases form a code for proteins? Biochemists began to crack the code when they discovered that a group of three nucleotides codes for one amino acid. For example, a sequence of three uracil nucleotides in mRNA (U-U-U) results in the amino acid phenylalanine being placed in a protein. Each set of three nitrogen bases in mRNA coding for an amino acid is known as a **codon.** You can follow the biochemists' reasoning for why three bases are needed by doing the *Problem-Solving Lab* on this page.

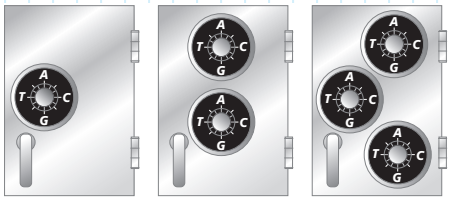
The order of nitrogen bases in the mRNA will determine the type and order of amino acids in a protein. Sixty-four combinations are possible

Problem-Solving Lab 11-2 Formulating Models

How many nitrogen 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 codons were needed. If one nucleotide coded for an amino acid, then only four amino acids could be represented. How many nucleotides are needed?

Analysis

Examine the three safes. Letters representing nitrogen 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. 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 amino acids known?
2. Could a nitrogen base (A, T, C, or G) taken one at a time code for 20 different amino acids? Explain.
3. 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 amino acids known?
4. Could nitrogen bases taken two at a time code for 20 different amino acids? Explain.
5. Using the same procedure for safe 3, see whether the total possible combinations equal or surpass the total number of amino acids known.
6. Could nitrogen bases taken three at a time code for 20 different amino acids? Explain.
7. Does the analogy prove that three bases code for an amino acid? Explain.

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when a sequence of three bases is used; thus, 64 different mRNA codons are in the genetic code, shown in ***Table 11.2.*** Some codons do not code for amino acids; they provide instructions for assembling the protein. For example, UAA is a *stop* codon indicating that protein production 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.

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.

All organisms use the same genetic code for amino acids and assembling proteins; UAC codes for tyrosine in the messenger RNA of bacteria, birch trees, and bison. For this reason, the genetic code 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. If the DNA in all the human cells of an adult were lined up end-to-end, it would stretch to about 60 billion miles—about 16 times the distance from the sun to Pluto, the outermost

Table 11.2 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)	Histadine (CAU)	Arginine (CGU)	U
	Leucine (CUC)	Proline (CCC)	Histadine (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

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planet in our solar system. With proteins, as in software, elaborate things are constructed from a simple code.

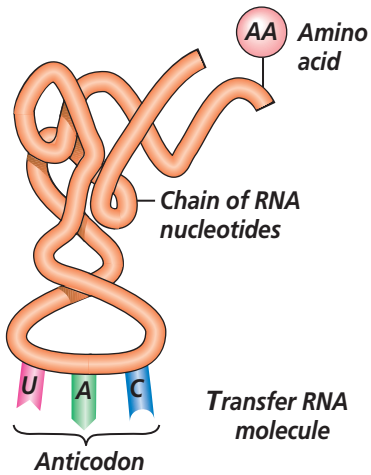
Translation: From mRNA to Protein

How is the language of mRNA translated into the language of proteins? The process of converting the information in a sequence of nitrogen bases in mRNA into a sequence of amino acids that make up a 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 that have no nucleus, the mRNA is made in the cytoplasm. In eukaryotic cells, mRNA leaves the nucleus through an opening in the nuclear membrane and travels to the cytoplasm. When the strands of mRNA arrive in the cytoplasm, ribosomes attach to them like clothespins 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), ***Figure 11.7.*** Each



MiniLab 11-1 Predicting

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 bonds 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 11.2*** on page 298 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

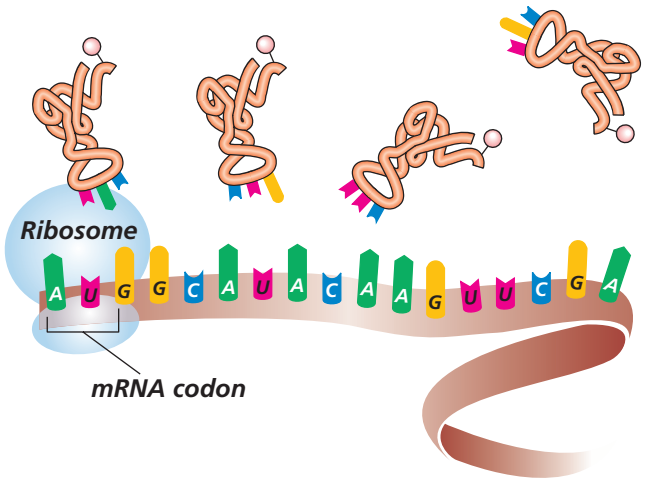
1. Where within the cell:
   a. are the DNA instructions located?
   b. does transcription occur?
   c. does translation occur?
2. Describe the structure of a tRNA molecule.
3. Explain why specific base pairing is essential to the processes of transcription and translation.

Figure 11.7
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 nitrogen bases, called an anticodon, that pair up with an mRNA codon during translation.

CONTENTS

Figure 11.8
A protein is formed by the process of translation.

A As translation begins, the starting end of the mRNA strand attaches to a ribosome. Then, tRNA molecules, each carrying a specific amino acid, approach the ribosome. When a tRNA anticodon pairs with the first mRNA codon, the two molecules temporarily join together.



tRNA molecule attaches to only one type of amino acid.

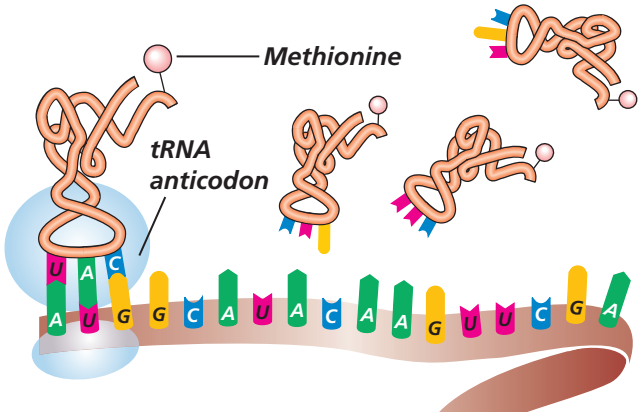
Correct translation of the mRNA message depends upon the joining of each mRNA codon with the correct tRNA molecule. How does a tRNA molecule carrying its amino acid recognize which codon to attach to? The answer again involves base pairing. On the opposite side of the transfer-RNA molecule from the amino-acid attachment site, there is a sequence of three nucleotides that are the complement of the nucleotides in the codon. These three nucleotides are called an anticodon because they bond to the codon of the messenger RNA. 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 A-C-A. This anticodon bonds with the mRNA codon U-G-U. Now, use ***Table 11.2*** to find the mRNA codon for tryptophan, then determine its tRNA anticodon.

Translating the mRNA code

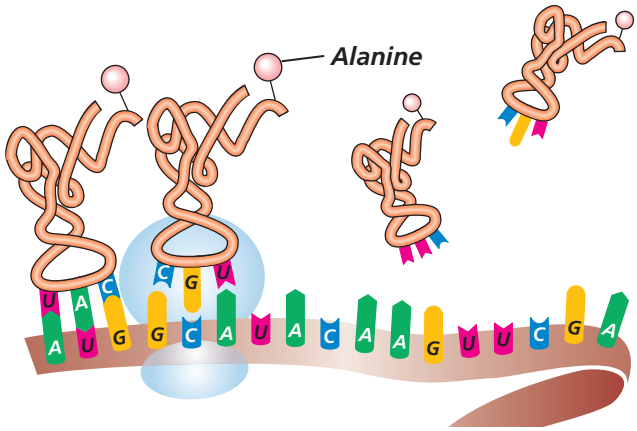
Follow the steps in ***Figure 11.8*** as you read how translation occurs. As translation begins, a tRNA molecule brings the first amino acid to the mRNA strand that is attached to the ribosome, ***Figure 11.8A.*** The anticodon forms a temporary bond with the codon of the mRNA strand, ***Figure 11.8B.*** This places the amino acid in the correct position for forming a 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 11.8C***. The amino acids bond, the first tRNA releases its amino acid and detaches from the mRNA, ***Figure 11.8D.*** 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 11.8E.***

Like Silly String sprayed into a friend's hair, amino acid chains become proteins when they are freed from the ribosome and twist and curl into complex three-dimensional shapes. Unlike Silly String, however, each protein chain forms the same shape every time it is produced. These proteins become enzymes and cell and tissue structures. The formation of protein, originating from the DNA code, produces the diverse and magnificent living world.

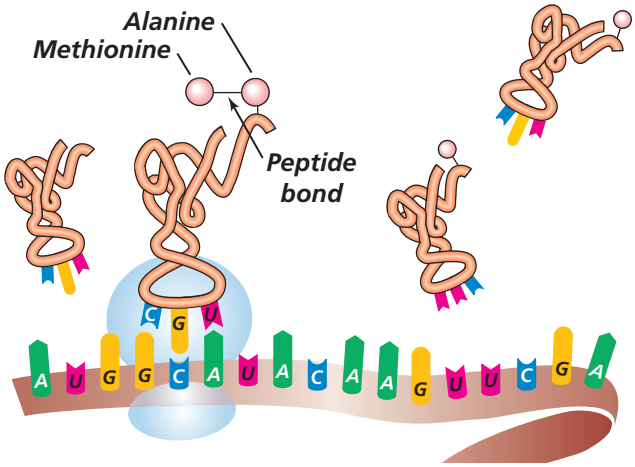
CONTENTS



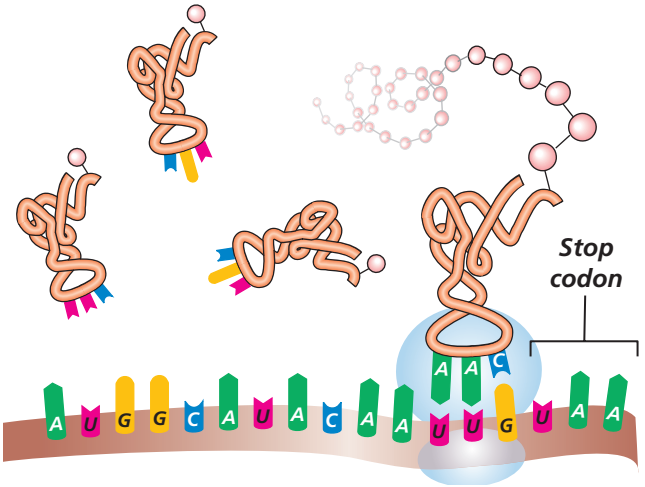
B Usually, the first codon on mRNA is AUG, which codes for the amino acid methionine. AUG signals the start of protein synthesis. When this signal is given, the ribosome slides along the mRNA to the next codon.



C A new tRNA molecule carrying an amino acid pairs with the second mRNA codon.



D When the first and second amino acids are in place, an enzyme joins them by forming a peptide bond between them.



E As the process continues, a chain of amino acids is formed until the ribosome reaches a *stop* codon on the mRNA strand.

Section Assessment

Understanding Main Ideas

1. In what ways do the chemical structures of DNA and RNA differ?
2. What is a codon, and what does it represent?
3. What is the role of tRNA in protein synthesis?
4. Compare and contrast the final products of DNA replication and transcription.

Thinking Critically

5. You have learned that there is a *stop* codon that signals 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. **Sequencing** 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 *Organizing Information* in the **Skill Handbook.**

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.

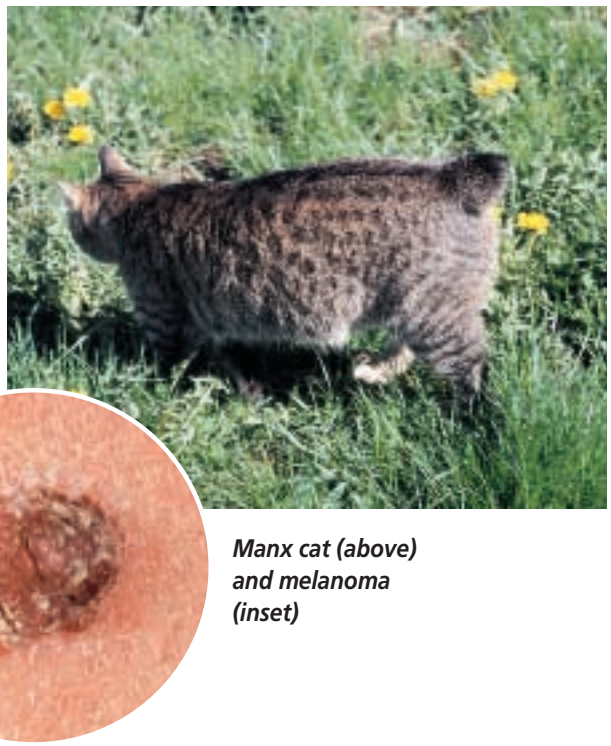
Vocabulary

mutation
point mutation
frameshift mutation
chromosomal mutation
mutagen

Section

11.3 Genetic Changes

DNA controls the structures and functions of a cell. What happens when the sequence of DNA nucleotides is changed in a gene? Sometimes it may have little or no harmful effect, as in this tailless Manx 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 the type of skin cancer shown here, UV rays from the sun change the DNA and cause the cells to grow and divide rapidly.



Manx cat (above) and melanoma (inset)

Mutation: A Change in DNA

Radiation may be given off in the reactor areas of nuclear power plants. If a person is exposed to this radiation, serious problems may result. The gamma radiation found in nuclear reactors can break apart a molecule of DNA, causing the nucleotide sequence to be changed. For this reason, nuclear power plant workers wear radiation-detecting devices such as the ones shown in ***Figure 11.9***. As you know, the sequences of nucleotides in DNA molecules control the structure and function of cells. Any change in the DNA sequence that also changes the protein it codes for is called a **mutation**.

WORD Origin

mutation
From the Latin word *mutare*, meaning "to change." Mutations are changes in DNA.

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 these cells take 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 is so severe that the

Figure 11.9
Nuclear power plant workers wear radiation badges (a) and pocket dosimeters (b) to monitor their exposure to radiation.

a

b

resulting protein is nonfunctional, and the embryo does 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. 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 make a muscle cell lose its ability to make a protein that contracts, or a skin cell may lose its elasticity. When that cell divides, the

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 their 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.

BIOLOGY Online

For more careers in related fields, be sure to check the Glencoe Science Web site.
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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 the disease called cancer. As you learned earlier, cancer is the uncontrolled dividing of cells. Cancer may result from gene mutations. For example, ultraviolet radiation in sunlight can change the DNA in skin cells, altering their behavior. The cells reproduce rapidly, causing skin cancer.

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 two sentences below to see 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 nitrogen 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 11.10A*** shows what can happen with a point mutation.

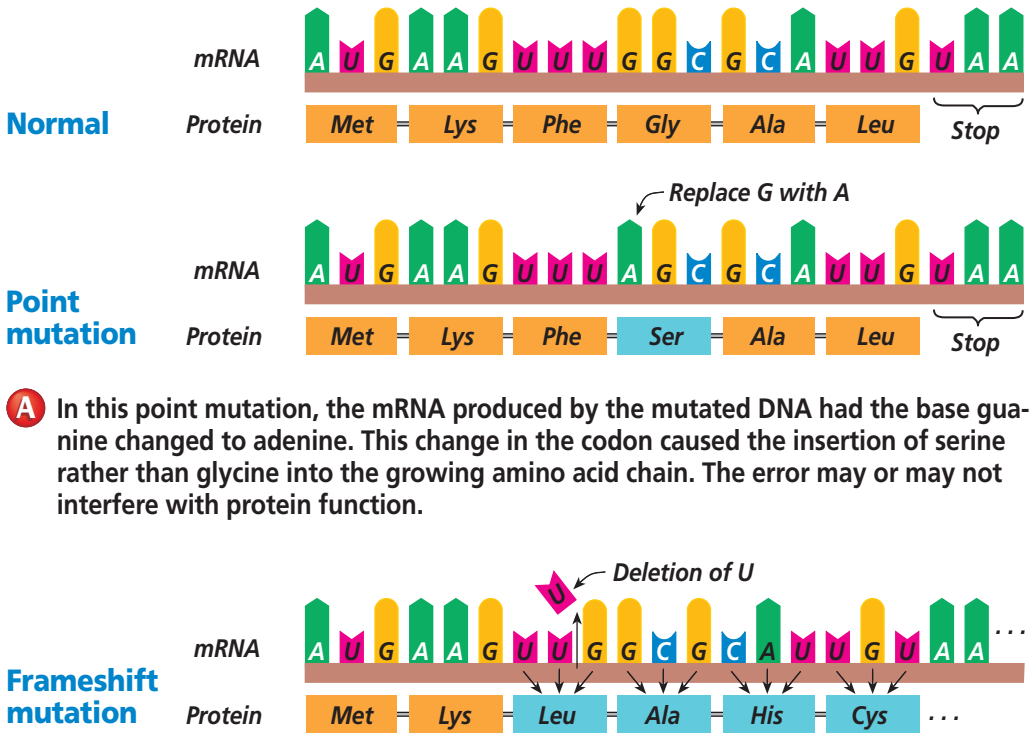

Figure 11.10
The results of a point mutation and a frameshift mutation are different. The diagrams show the mRNA that would be formed from each corresponding DNA.

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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Frameshift mutations

When the mRNA strand moves across the ribosome, 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? 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 11.10B.*** 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 also result from the addition of a single base. A mutation in which a single base is added 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 an actual human mutation.

Chromosomal Mutations

Changes may occur at the level of chromosomes as well as in genes. Mutations 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 changes in chromosomes are called **chromosomal mutations.**

Problem-Solving Lab 11-3

Making and Using Tables

What type of mutation results in sickle-cell anemia?
A condition 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.

Analysis

Table 11.3 shows the sequence of bases in a short segment of the DNA that controls the order of amino acids in the protein, hemoglobin.

Table 11.3 DNA base sequences

Normal hemoglobin	GGG CTT CTT TTT
Sickled hemoglobin	GGG CAT CTT TTT

Thinking Critically

1. Use ***Table 11.2*** on page 298 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. Does this genetic change illustrate a point mutation or frameshift mutation? Explain your answer.
3. Explain why the correct sequence of DNA bases is important to normal development of proteins.
4. Assume that the base sequence reads GGG CTT CTT AAA instead of the normal sequence for hemoglobin. Would this result in sickled hemoglobin? Explain your answer.

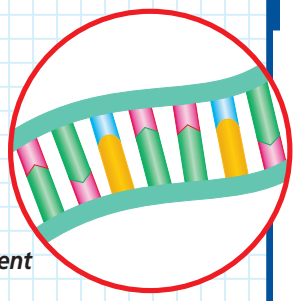
Effects of chromosomal mutations

Chromosomal mutations occur in all living organisms, but they are especially common in plants. Such mutations affect the distribution of genes to gametes during meiosis because they cause nondisjunction, the failure of chromosomes to separate. Nondisjunction occurs because homologous chromosomes cannot pair correctly when one has extra or missing parts. 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

Making and Using 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.



DNA segment

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 11.2*** 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

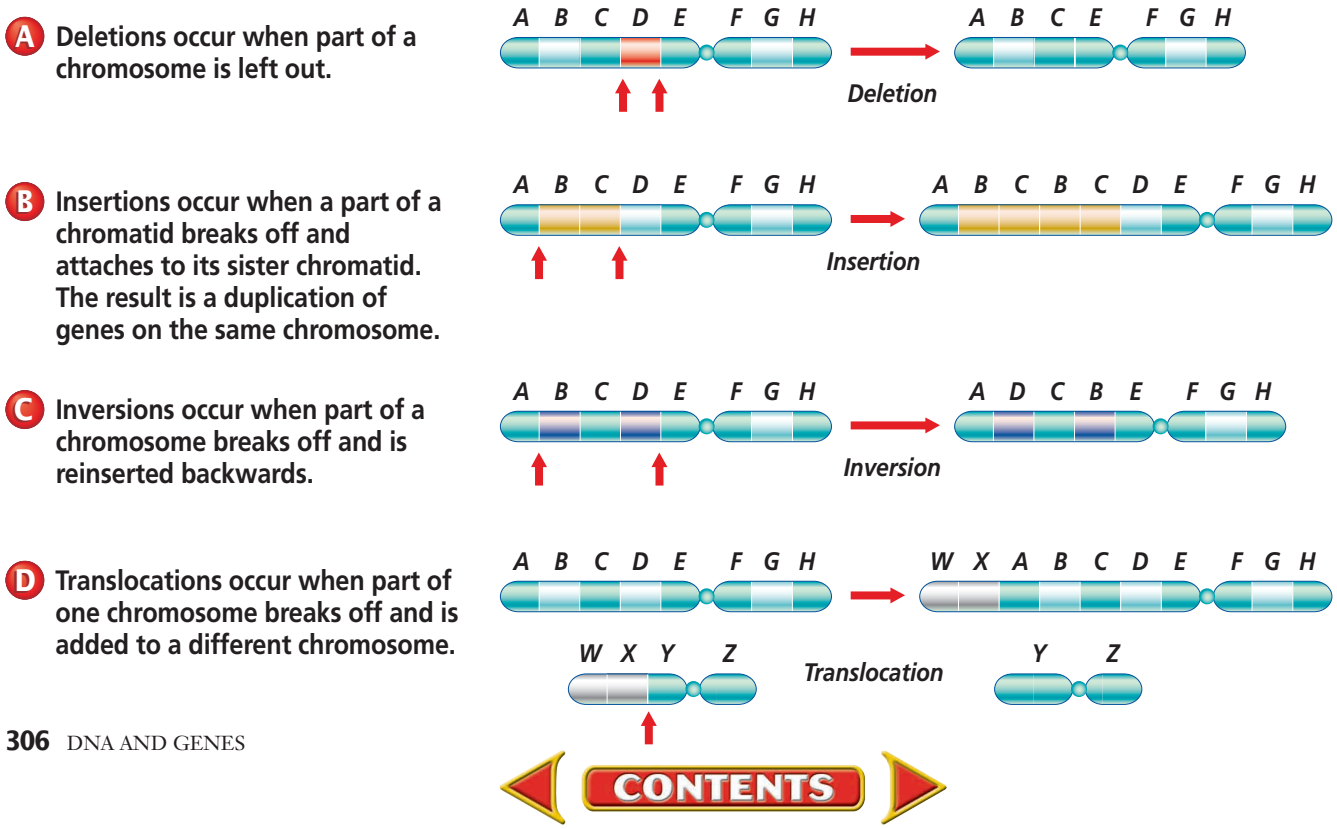
1. Which change in DNA was a point mutation? Which was a frameshift mutation?
2. In what way did the point mutation affect the protein?
3. How did the frameshift mutation affect the protein?

Few chromosome 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 11.11.***

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. As you learned earlier, gamma radiation is capable of causing mutations. Any agent that can cause a change in DNA is called a **mutagen** (MYEWT uh jun). Mutagens include high energy radiation, chemicals, and even high temperatures.

Figure 11.11
Study the four kinds of chromosomal mutations.



CONTENTS

Forms of radiation, such as X rays, cosmic rays, ultraviolet light, and nuclear radiation, are dangerous mutagens because they contain a large amount of energy that can blast DNA apart. The breaking and reforming of a double-stranded DNA molecule can result in deletions. Radiation can also cause substitutions of incorrect nucleotides in the DNA.

Chemical mutagens include dioxins, asbestos, benzene, cyanide, and formaldehyde, compounds that are commonly found in buildings and in the environment, ***Figure 11.12.*** These mutagens are highly reactive compounds that interact with the DNA molecule and cause changes. Chemical mutagens usually result in a substitution mutation.

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 11.12
Asbestos was formerly used to insulate buildings. It is now known to cause lung cancer and other lung diseases and must be removed from these buildings, as shown here.

Section Assessment

Understanding Main Ideas

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

Thinking Critically

5. Why do you think low levels of mutation might be an adaptive advantage to a species, whereas high levels of mutation might be a disadvantage?

Skill Review

6. **Recognizing Cause and Effect** In an experiment with rats, the treatment group receives radiation while the control group does not. Months later, the treatment group has a greater percentage of rats with cancer and newborn rats with birth defects than the control group. Explain these observations. For more help, refer to *Thinking Critically* in the **Skill Handbook.**

INVESTIGATE BioLab

RNA Transcription

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, and 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 copied.

Materials

construction paper, 5 colors
scissors
clear tape

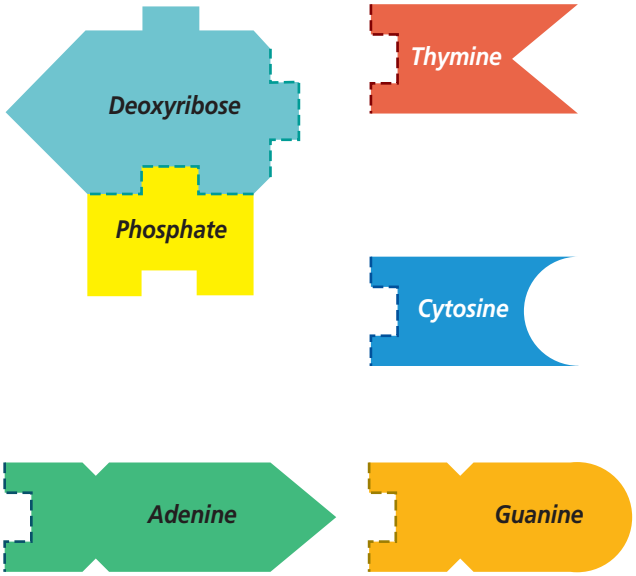
Safety Precautions

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

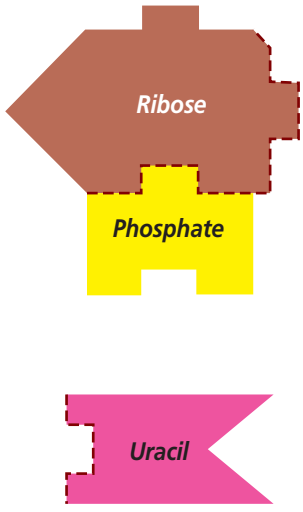
Skill Handbook

Use the **Skill Handbook** if you need additional help with this lab.

Parts for DNA Nucleotides

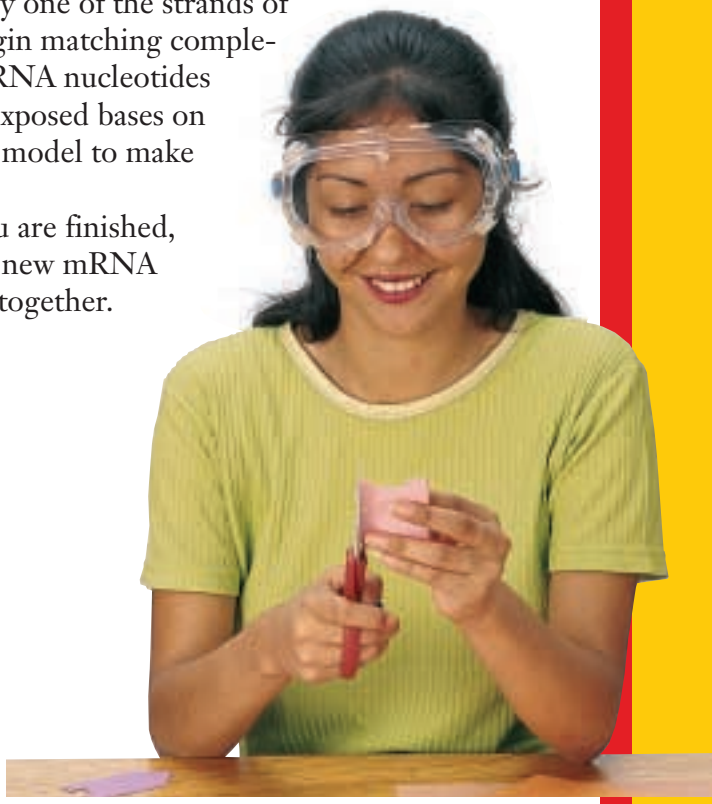


Extra Parts for RNA Nucleotides



Procedure

1. Copy the illustrations of the four different DNA nucleotides onto your construction paper, making sure that each different nucleotide is on a different color paper. You should 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 before.
4. Fasten your molecule together using clear tape. Do not tape across base pairs.
5. As in step 1, copy the illustrations of A, G, and C 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 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.



Analyze and Conclude

1. **Observing and Inferring** 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. **Recognizing Cause and Effect** Explain how the structure of DNA enables the molecule to be easily transcribed. Why is this important for genetic information?
3. **Relating Concepts** Why is RNA important to the cell? How does an mRNA molecule carry information from DNA?

Going Further

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

BIOLOGY Online To find out more about DNA, visit the Glencoe Science Web site.

science.glencoe.com

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.

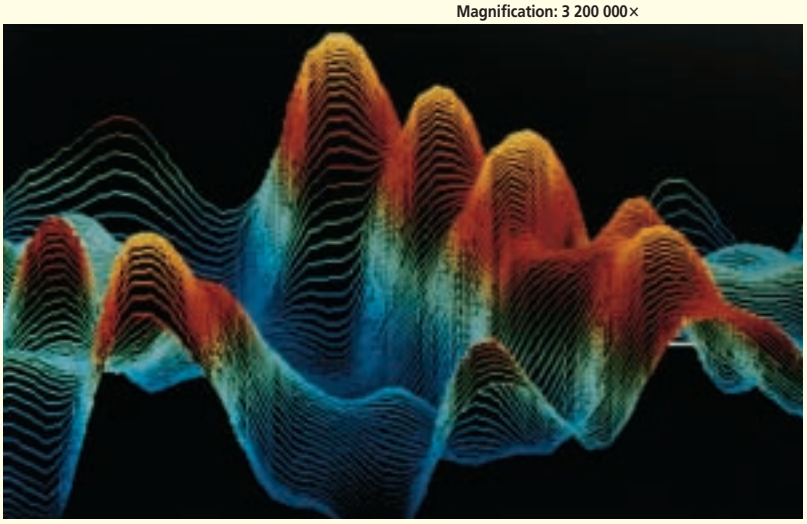
The scanning tunneling microscope (STM)

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. In 1998, for example, biologists used the AFM to observe the behavior of an enzyme called RNA polymerase. This enzyme is involved in transcription. The AFM images show how the polymerase molecule binds to a strand of DNA and creates a strand of mRNA by gathering nucleotides from the surrounding liquid.

Magnification: 3 200 000×



STM image of DNA

Applications for the Future

Biologists have used a combination of lasers and an AFM to study the physical properties of DNA molecules. Laser "tweezers" hold down one end of a coiled DNA helix and pull on the other end. The AFM measures the forces that hold the strand together and the forces that cause it to coil and uncoil as it performs its functions in the cell.

Investigating the Technology

Thinking Critically What advantages do scanning probe microscopes have over other types of microscopes?

BIOLOGY Online To find out more about microscopes, visit the Glencoe Science Web site.
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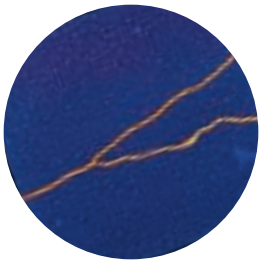
CLICK HERE

Chapter 11 Assessment

Summary

Section 11.1

DNA: The Molecule of Heredity



Main Ideas

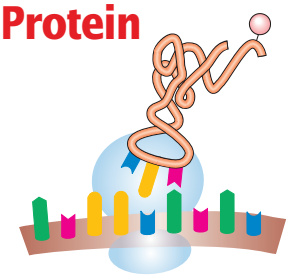
- DNA, the genetic material of organisms, is composed of four kinds of nucleotides. A DNA molecule consists of two strands of nucleotides with sugars and phosphates on the outside and bases paired by hydrogen bonding on the inside. The paired strands form a twisted-zipper shape called a double helix.
- Because adenine can pair only with thymine, and guanine can pair only with cytosine, DNA can replicate itself with great accuracy. This process keeps the genetic information constant through cell division and during reproduction.

Vocabulary

DNA replication (p. 290)
double helix (p. 289)
nitrogen base (p. 288)

Section 11.2

From DNA to Protein

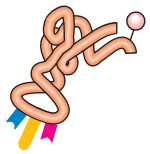


Main Ideas

- 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.
- The order of nucleotides in DNA determines the order of nucleotides in messenger RNA in a process called transcription.
- Translation is a process through which the order of bases in messenger RNA codes for the order of amino acids in a protein.

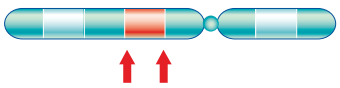
Vocabulary

codon (p. 297)
messenger RNA (p. 295)
ribosomal RNA (p. 296)
transcription (p. 296)
transfer RNA (p. 296)
translation (p. 299)



Section 11.3

Genetic Changes



Main Ideas

- 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. 305)
frameshift mutation (p. 305)
mutagen (p. 306)
mutation (p. 302)
point mutation (p. 304)

Understanding Main Ideas

1. Which of the following processes requires DNA replication?
   a. transcription
   b. translation
   c. mitosis
   d. protein synthesis

2. In which of the following processes does the DNA unzip?
   a. transcription and translation
   b. transcription and replication
   c. replication and translation
   d. all of these

Chapter 11 Assessment

3. Which DNA strand can base pair to the following DNA strand?

a. T-A-C-G-A-T
b. A-T-G-C-T-A
c. U-A-C-G-A-U
d. A-U-G-C-U-A

4. Which of the following nucleotide chains could be part of a molecule of RNA?
a. A-T-G-C-C-A
b. A-A-T-A-A-A
c. G-C-C-T-T-G
d. A-U-G-C-C-A

5. Which of the following mRNA codons would cause synthesis of a protein to terminate? Refer to ***Table 11.2.***
a. G-G-G
b. U-A-C
c. U-A-G
d. A-A-G

6. A DNA sequence of A-C-C would create an mRNA codon for which amino acid? Refer to ***Table 11.2.***
a. tryptophan
b. serine
c. leucine
d. phenylalanine

7. 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

8. Which of the following base pairs would not be found in a cell?
a. adenine—thymine
b. cytosine—guanine
c. thymine—uracil
d. adenine—uracil

9. A protein is assembled amino acid-by-amino acid during the process of _____.
a. replication
b. translation
c. transcription
d. mutation

THE PRINCETON REVIEW

Test-Taking Tip

Use as Much Time as You Can

You will not get extra points for finishing early. Work slowly and carefully on any test and make sure you don't make careless errors because you are hurrying to finish.

10. A deer is born normal, but UV rays cause a mutation in its retina. Which of the following statement 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.

11. In the process of _____, enzymes make an RNA copy of a DNA strand.

12. The RNA copy that carries information from DNA in the nucleus into the cytoplasm is _____ RNA.

13. DNA is copied before a cell divides in the process called _____.

14. Molecules of _____ bring amino acids to the _____ for assembly into proteins.

15. The shape of a molecule of DNA is called a _____.

16. RNA has a ribose sugar, whereas DNA has a _____ sugar.

17. Nucleotides form base pairs through a weak bond called a _____ bond.

18. A female lab rat is exposed to X rays. Its future offspring will be affected only if a mutation occurs in the rat's _____ cells.

19. Chemical Q causes the following change in the sequences of nucleotides. This change is an example of a _____. Chemical Q is a _____.

20. DNA _____ is necessary before a cell divides so each cell has a complete copy of the chromosomes.

Applying Main Ideas

21. Explain why a mutation in a lung cell would not be passed on to offspring.

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Chapter 11 Assessment

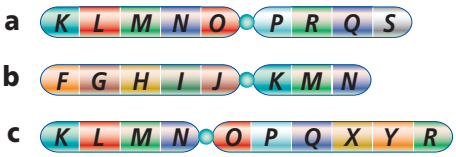
22. Explain why codons can't consist of two bases instead of three for each amino acid.

23. A bricklayer has an assistant who brings bricks to the bricklayer so she can build a wall. What part of translation most closely resembles the assistant's job? What do the bricks represent?

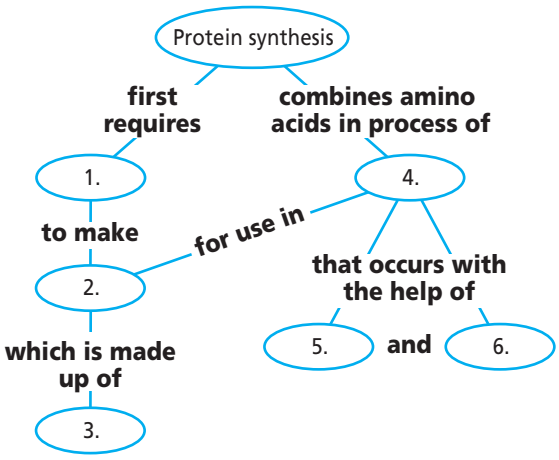
Thinking Critically

24. Making Inferences Explain how the universality of the genetic code is evidence that all organisms alive today evolved from a common ancestor in the past.

25. Analyzing Identify the type of chromosomal mutation illustrated in each diagram below.



26. Concept Mapping Complete the concept map by using the following vocabulary terms: transfer RNA, codons, messenger RNA, transcription, translation, ribosomal RNA.

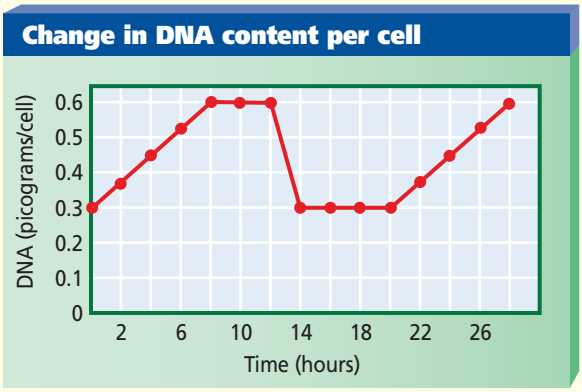


CD-ROM

For additional review, use the assessment options for this chapter found on the ***Biology: The Dynamics of Life Interactive CD-ROM*** and on the Glencoe Science Web site.
science.glencoe.com

Assessing Knowledge & Skills

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.



Interpreting Data Use the data in the graph to answer the following questions.

1. During the course of the experiment, these cells went through cell division. What is this type of division called?
a. transcription **c.** mitosis
b. translation **d.** meiosis

2. During which hours were the cells carrying out cell division?
a. 0-8 hours **c.** 12-14 hours
b. 8-10 hours **d.** 14-20 hours

3. Which phase of the cell cycle were the cells in during hours 2-6?
a. interphase **c.** prophase
b. telophase **d.** anaphase

4. If you added radioactive thymine to the culture at 0 hour, what would happen to the amount incorporated into the DNA between hours 20 and 28 relative to the amount at 0 hour?
a. stay the same **c.** double
b. divide in half **d.** triple

5. Predicting Predict what will be the DNA content of the cells, in picograms, at 33 hours.

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