8.4 Transcription

KEY CONCEPT Transcription converts a gene into a single-stranded RNA molecule.

MAIN IDEAS

- RNA carries DNA's instructions.
- Transcription makes three types of RNA.
- The transcription process is similar to replication.

VOCABULARY

central dogma, p. 239
RNA, p. 239
transcription, p. 240
RNA polymerase, p. 240
messenger RNA (mRNA), p. 240
ribosomal RNA (rRNA), p. 240
transfer RNA (tRNA), p. 240

CALIFORNIA STANDARDS

1.d *Students know* the central dogma of molecular biology outlines the flow of information from transcription of ribonucleic acid (RNA) in the nucleus to translation of proteins on ribosomes in the cytoplasm.

5.a *Students know* the general structures and functions of DNA, RNA, and protein.

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

Connect Suppose you want to play skeeball at a game center, but the skeeball lane only takes tokens. You only have quarters. Do you go home in defeat? Stand idly by as someone else becomes high scorer? No, you exchange your quarters for tokens and then proceed to show the other players how it's done. In a similar way, your cells cannot make proteins directly from DNA. They must convert the DNA into an intermediate molecule called RNA, or ribonucleic acid. That conversion process, called transcription, is the focus of this section.

MAIN IDEA

RNA carries DNA's instructions.

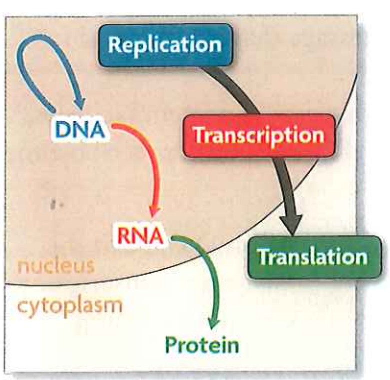
Soon after his discovery of DNA structure, Francis Crick defined the **central dogma** of molecular biology, which states that information flows in one direction, from DNA to RNA to proteins. The central dogma involves three processes, as shown in **FIGURE 8.10.**

- Replication, as you just learned, copies DNA (blue arrow).
- Transcription converts a DNA message into an intermediate molecule, called RNA (red arrow).
- Translation interprets an RNA message into a string of amino acids, called a polypeptide. Either a single polypeptide or many polypeptides working together make up a protein (green arrow).

In prokaryotic cells, replication, transcription, and translation all occur in the cytoplasm at approximately the same time. In eukaryotic cells, where DNA is located inside the nuclear membrane, these processes are separated both in location and time. Replication and transcription occur in the nucleus, while translation occurs in the cytoplasm. In addition, the RNA in eukaryotic cells goes through a processing step before it can be transported out of the nucleus. Unless otherwise stated, the rest of this chapter describes how these processes work in eukaryotic cells.

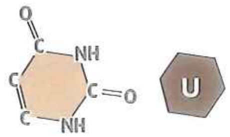
RNA acts as an intermediate link between DNA in the nucleus and protein synthesis in the cytoplasm. Like DNA, **RNA,** or ribonucleic acid, is a chain of nucleotides, each made of a sugar, a phosphate group, and a nitrogen-containing base. You can think of RNA as a temporary copy of DNA that is used and then destroyed.

FIGURE 8.10 The central dogma describes the flow of information from DNA to RNA to proteins. It involves three major processes, shown in a eukaryotic cell below.



Connecting CONCEPTS

DNA Structure As you learned in **Section 8.2**, nucleotides are made of a phosphate group, a sugar, and a nitrogen-containing base. In DNA, the four bases are adenine, cytosine, guanine, and thymine. In RNA, uracil (below) replaces thymine and pairs with adenine.



RNA differs from DNA in three significant ways. First, the sugar in RNA is ribose, which has one additional oxygen atom not present in DNA's sugar (deoxyribose). Second, RNA has the base uracil in place of thymine. Uracil, like thymine, forms base pairs with adenine. Third, RNA is a single strand of nucleotides, in contrast to the double-stranded structure of DNA. This single-stranded structure allows some types of RNA to form complex three-dimensional shapes. As a result, some RNA molecules can catalyze reactions much as enzymes do.

Contrast How do DNA and RNA differ?

MAIN IDEA

Transcription makes three types of RNA.

Transcription is the process of copying a sequence of DNA to produce a complementary strand of RNA. During the process of transcription, a gene—not an entire chromosome—is transferred into an RNA message. Just as replication is catalyzed by DNA polymerase, transcription is catalyzed by **RNA polymerases,** enzymes that bond nucleotides together in a chain to make a new RNA molecule. RNA polymerases are very large enzymes composed of many proteins that play a variety of roles in the transcription process. **FIGURE 8.11** shows the basic steps of transcription in eukaryotic cells.

1. With the help of other proteins and DNA sequences, RNA polymerase recognizes the transcription start site of a gene. A large transcription complex consisting of RNA polymerase and other proteins assembles on the DNA strand and begins to unwind a segment of the DNA molecule, until the two strands separate from each other.
2. RNA polymerase, using only one strand of DNA as a template, strings together a complementary strand of RNA nucleotides. RNA base pairing follows the same rules as DNA base pairing, except that uracil, not thymine, pairs with adenine. The growing RNA strand hangs freely as it is transcribed, and the DNA helix zips back together.
3. Once the entire gene has been transcribed, the RNA strand detaches completely from the DNA. Exactly how RNA polymerase recognizes the end of a transcription unit is complicated. It varies with the type of RNA.

VOCABULARY

The word *transcribe* means "to make a written copy of." *Transcription* is the process of transcribing. A *transcript* is the copy produced by transcription.

Transcription produces three major types of RNA molecules. Not all RNA molecules code for proteins, but most play a role in the translation process. Each type of RNA molecule has a unique function.

- **Messenger RNA (mRNA)** is an intermediate message that is translated to form a protein.
- **Ribosomal RNA (rRNA)** forms part of ribosomes, a cell's protein factories.
- **Transfer RNA (tRNA)** brings amino acids from the cytoplasm to a ribosome to help make the growing protein.

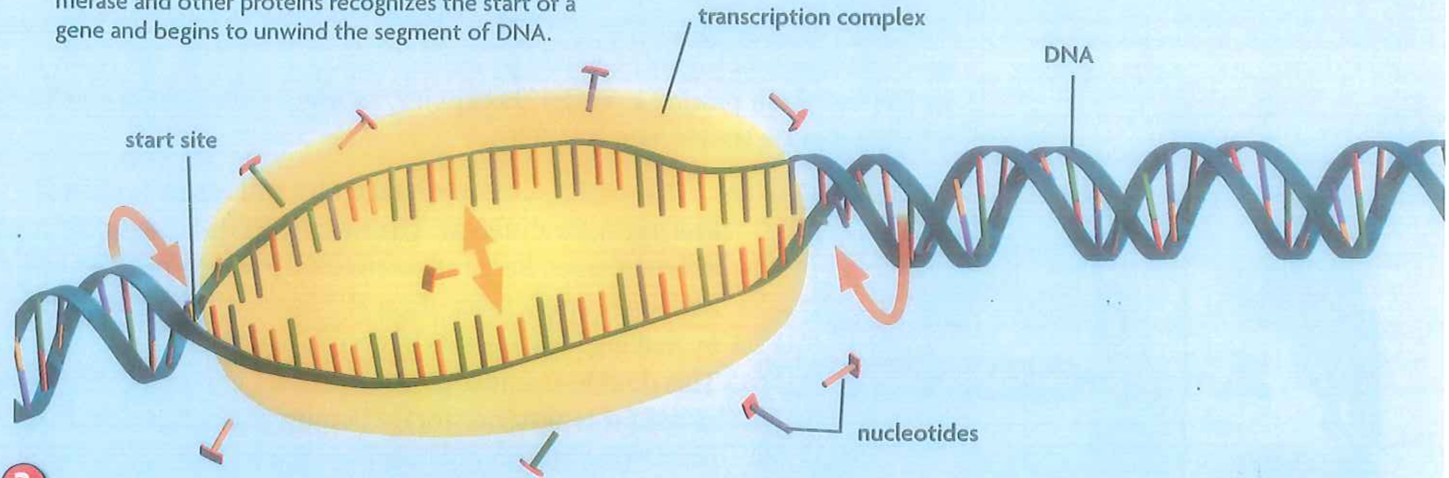
Remember that the RNA strand must be processed before it can exit the nucleus of a eukaryotic cell. This step occurs during or just after transcription. However, we will next examine translation and then return to processing.

Analyze Explain why transcription occurs in the nucleus of eukaryotes.

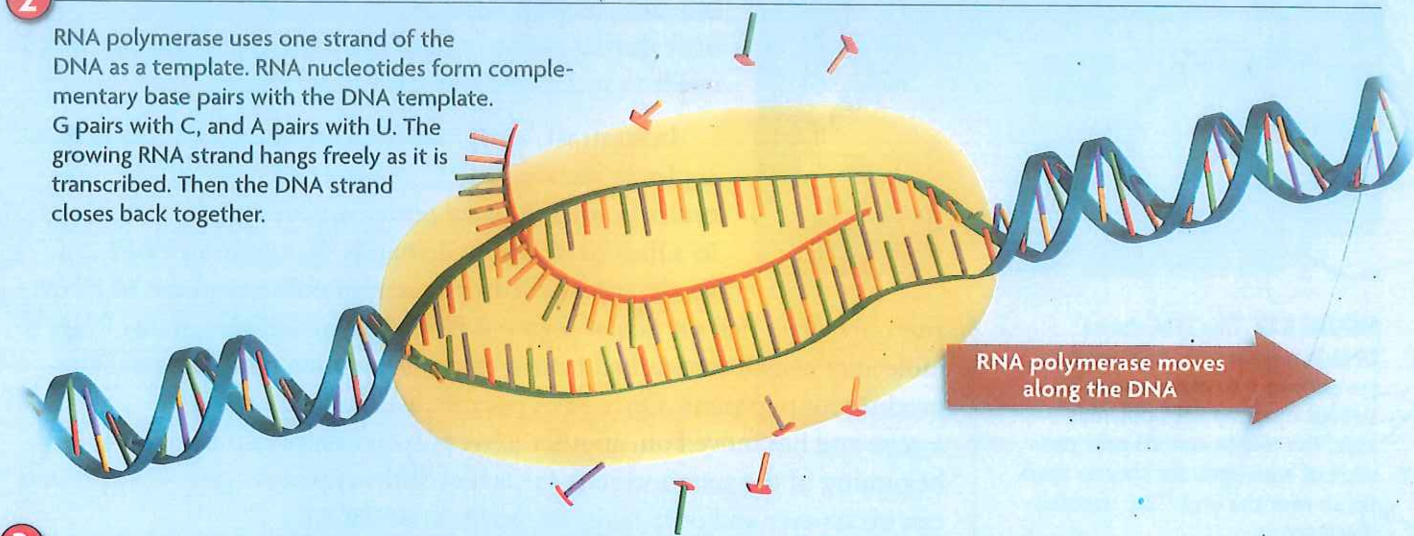
FIGURE 8.11 Transcription

Transcription produces an RNA molecule from a DNA template. Like DNA replication, this process takes place in the nucleus in eukaryotic cells and involves both DNA unwinding and nucleotide base pairing.

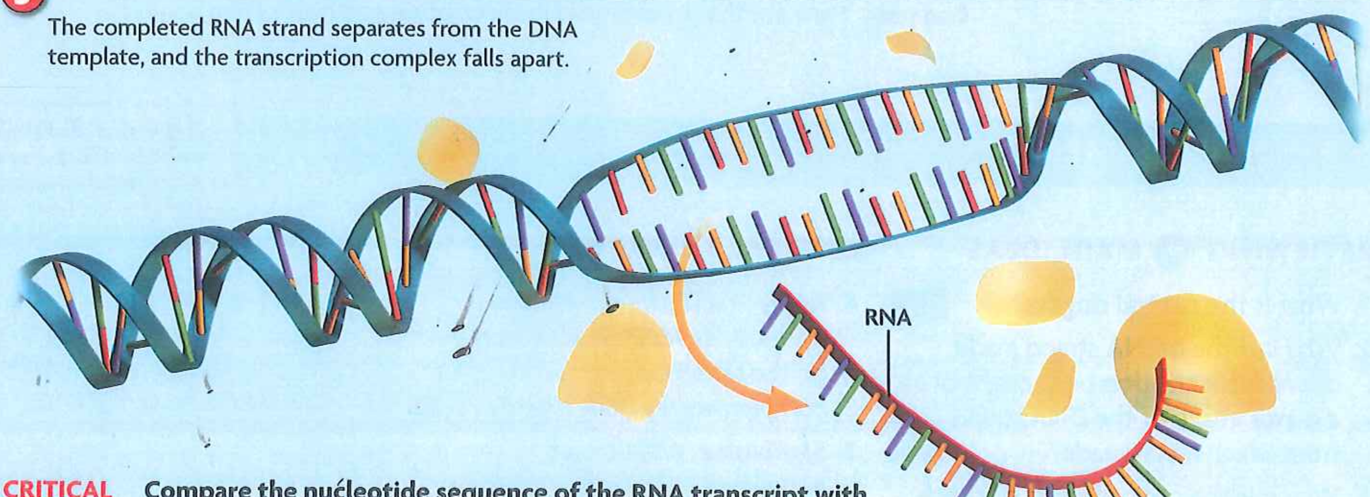
1 A large transcription complex made of RNA polymerase and other proteins recognizes the start of a gene and begins to unwind the segment of DNA.



2 RNA polymerase uses one strand of the DNA as a template. RNA nucleotides form complementary base pairs with the DNA template. G pairs with C, and A pairs with U. The growing RNA strand hangs freely as it is transcribed. Then the DNA strand closes back together.



3 The completed RNA strand separates from the DNA template, and the transcription complex falls apart.



CRITICAL VIEWING **Compare the nucleotide sequence of the RNA transcript with the nucleotide sequence of the nontemplate strand of DNA.**

MAIN IDEA

The transcription process is similar to replication.

The processes of transcription and replication share many similarities. Both processes occur within the nucleus of eukaryotic cells. Both are catalyzed by large, complex enzymes. Both involve unwinding of the DNA double helix. And both involve complementary base pairing to the DNA strand. In addition, both processes are highly regulated by the cell. Just as a cell does not replicate its DNA without passing a critical checkpoint, so, too, a cell carefully regulates which genes are transcribed into RNA.

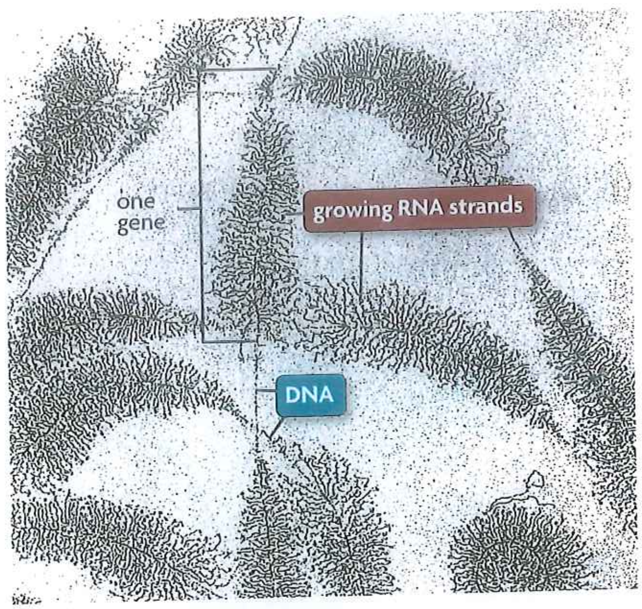


FIGURE 8.12 This TEM shows DNA in a eukaryotic cell being transcribed into numerous mRNA strands by many RNA polymerases. The mRNA strands near the start of each gene are shorter than those near the end. (TEM; magnification 13,000×)

The end results of transcription and replication, however, are quite different. The two processes accomplish very different tasks. Replication ensures that each new cell will have one complete set of genetic instructions. It does this by making identical sets of double-stranded chromosomes. This double-stranded structure makes DNA especially well suited for long-term storage because it helps protect DNA from being broken down and from potentially harmful interactions with other molecules. Replication occurs only once during each round of the cell cycle because each cell needs to make only one copy of its DNA.

In contrast, a cell may need hundreds or thousands of copies of certain proteins, or the rRNA and tRNA molecules needed to make proteins. Transcription enables a cell to adjust to changing demands. It does so by making a single-stranded complement of only a segment of DNA and only when that particular segment is needed. In addition, many RNA molecules can be transcribed from a single gene at the same time to help produce more protein. Once RNA polymerase has transcribed one portion of a gene and has moved on, another RNA polymerase can attach itself to the beginning of the gene and start the transcription process again. This process can occur over and over again, as shown in **FIGURE 8.12**.

Compare **How are the processes of transcription and replication similar?**

8.4 ASSESSMENT

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REVIEWING MAIN IDEAS

1. What is the **central dogma**? 1.d
2. Why can the **mRNA** strand made during **transcription** be thought of as a mirror image of the DNA strand from which it was made? 5.b
3. Why might a cell make lots of **rRNA** but only one copy of DNA? 5.a

CRITICAL THINKING

4. **Apply** If a DNA segment has the nucleotides AGCCTAA, what would be the nucleotide sequence of the complementary **RNA** strand? 5.b
5. **Synthesize** What might geneticists learn about genes by studying RNA? 5.a

Connecting CONCEPTS

6. **Cell Cycle** You know that a healthy cell cannot pass the G_2 checkpoint until all of its DNA has been copied. Do you think that a cell must also transcribe all of its genes into RNA to pass this checkpoint? Explain.

8.5 Translation

KEY CONCEPT Translation converts an mRNA message into a polypeptide, or protein.

MAIN IDEAS

- Amino acids are coded by mRNA base sequences.
- Amino acids are linked to become a protein.

VOCABULARY

translation, p. 243
codon, p. 243
stop codon, p. 244
start codon, p. 244
anticodon, p. 245

Review
peptide bond

CALIFORNIA STANDARDS

4.a *Students know* the general pathway by which ribosomes synthesize proteins, using tRNAs to translate genetic information in mRNA.

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

Connect As you know, translation is a process that converts a message from one language into another. For example, English words can be translated into Spanish words, into Chinese characters, or into the hand shapes and gestures of sign language. Translation occurs in cells too. Cells translate an RNA message into amino acids, the building blocks of proteins. But unlike people who use many different languages, all cells use the same genetic code.

MAIN IDEA

Amino acids are coded by mRNA base sequences.

Translation is the process that converts, or translates, an mRNA message into a polypeptide. One or more polypeptides make up a protein. The "language" of nucleic acids uses four nucleotides—A, G, C, and T in DNA; or A, G, C, and U in RNA. The "language" of proteins, on the other hand, uses 20 amino acids. How can four nucleotides code for 20 amino acids? Just as letters are strung together in the English language to make words, nucleotides are strung together to code for amino acids.

Connecting CONCEPTS

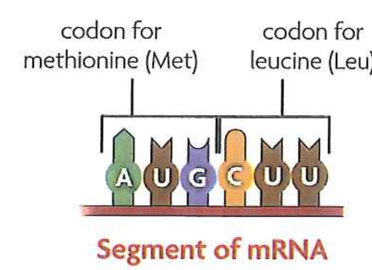
Biochemistry Recall from **Chapter 2** that amino acids are the building blocks of proteins. Although there are many types of amino acids, only the same 20 types make up the proteins of almost all organisms.

Triplet Code

Different words have different numbers of letters. In the genetic code, however, all of the "words," called codons, are made up of three letters. A **codon** is a three-nucleotide sequence that codes for an amino acid. Why is the genetic code read in units of three nucleotides? Well, we can't entirely answer that question, but consider the possibilities. If one nucleotide coded for one amino acid, RNA could code for only four amino acids. If two nucleotides coded for one amino acid, RNA could code for 16 (4^2) amino acids—still not enough. But if three nucleotides coded for one amino acid, RNA could code for 64 (4^3) amino acids, plenty to cover the 20 amino acids used to build proteins in the human body and most other organisms.

VISUAL VOCAB

A **codon** is a sequence of three nucleotides that codes for an amino acid.



Translation

FIGURE 8.13 Genetic Code: mRNA Codons

The genetic code matches each mRNA codon with its amino acid or function.

Suppose you want to determine which amino acid is encoded by the CAU codon.

1. Find the first base, C, in the left column.
2. Find the second base, A, in the top row. Find the box where these two intersect.
3. Find the third base, U, in the right column. CAU codes for histidine, abbreviated as His.

First base	Second base: U		Second base: C		Second base: A		Second base: G		Third base
U	UUU	phenylalanine (Phe)	UCU	serine (Ser)	UAU	tyrosine (Tyr)	UGU	cysteine (Cys)	U
U	UUC	phenylalanine (Phe)	UCC	serine (Ser)	UAC	tyrosine (Tyr)	UGC	cysteine (Cys)	C
U	UUA	leucine (Leu)	UCA	serine (Ser)	UAA	STOP	UGA	STOP	A
U	UUG	leucine (Leu)	UCG	serine (Ser)	UAG	STOP	UGG	tryptophan (Trp)	G
C	CUU	leucine (Leu)	CCU	proline (Pro)	CAU	histidine (His)	CGU	arginine (Arg)	U
C	CUC	leucine (Leu)	CCC	proline (Pro)	CAC	histidine (His)	CGC	arginine (Arg)	C
C	CUA	leucine (Leu)	CCA	proline (Pro)	CAA	glutamine (Gln)	CGA	arginine (Arg)	A
C	CUG	leucine (Leu)	CCG	proline (Pro)	CAG	glutamine (Gln)	CGG	arginine (Arg)	G
A	AUU	isoleucine (Ile)	ACU	threonine (Thr)	AAU	asparagine (Asn)	AGU	serine (Ser)	U
A	AUC	isoleucine (Ile)	ACC	threonine (Thr)	AAC	asparagine (Asn)	AGC	serine (Ser)	C
A	AUA	isoleucine (Ile)	ACA	threonine (Thr)	AAA	lysine (Lys)	AGA	arginine (Arg)	A
A	AUG	methionine (Met)	ACG	threonine (Thr)	AAG	lysine (Lys)	AGG	arginine (Arg)	G
G	GUU	valine (Val)	GCU	alanine (Ala)	GAU	aspartic acid (Asp)	GGU	glycine (Gly)	U
G	GUC	valine (Val)	GCC	alanine (Ala)	GAC	aspartic acid (Asp)	GGC	glycine (Gly)	C
G	GUA	valine (Val)	GCA	alanine (Ala)	GAA	glutamic acid (Glu)	GGA	glycine (Gly)	A
G	GUG	valine (Val)	GCG	alanine (Ala)	GAG	glutamic acid (Glu)	GGG	glycine (Gly)	G

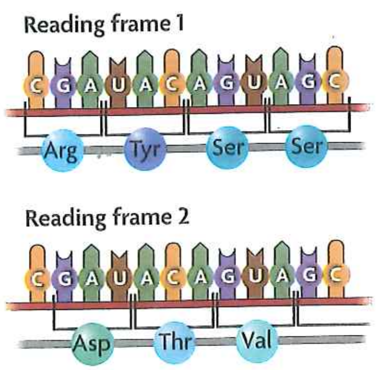
Apply Which amino acid would be encoded by the mRNA codon CGA?

As you can see in **FIGURE 8.13**, many amino acids are coded for by more than one codon. The amino acid leucine, for example, is represented by six different codons: CUU, CUC, CUA, CUG, UUA, and UUG. There is a pattern to the codons. In most cases, codons that represent the same amino acid share the same first two nucleotides. For example, the four codons that code for alanine each begin with the nucleotides GC. Therefore, the first two nucleotides are generally the most important in coding for an amino acid. As you will learn in Section 8.7, this feature makes DNA more tolerant of many point mutations.

In addition to codons that code for amino acids, three **stop codons** signal the end of the amino acid chain. There is also one **start codon,** which signals the start of translation and the amino acid methionine. This means that translation always begins with methionine. However, in many cases, this methionine is removed later in the process.

For the mRNA code to be translated correctly, codons must be read in the right order. Codons are read, without spaces, as a series of three nonoverlapping nucleotides. This order is called the reading frame. Changing the reading frame completely changes the resulting protein. It may even keep a protein from being made if a stop codon turns up early in the translation process. Therefore, punctuation—such as a clear start codon—plays an important role in the genetic code. **FIGURE 8.14** shows how a change in reading frame changes

FIGURE 8.14 Codons are read as a series of three nonoverlapping nucleotides. A change in the reading frame changes the resulting protein.



the resulting protein. When the mRNA strand is read starting from the first nucleotide, the resulting protein includes the amino acids arginine, tyrosine, and two serines. When the strand is read starting from the second nucleotide, the resulting protein includes aspartic acid, threonine, and valine.

Common Language

The genetic code is shared by almost all organisms—and even viruses. That means, for example, that the codon UUU codes for phenylalanine when that codon occurs in an armadillo, a cactus, a yeast, or a human. With a few minor exceptions, almost all organisms follow this genetic code. As a result, the code is often called universal. The common nature of the genetic code suggests that almost all organisms arose from a common ancestor. It also means that scientists can insert a gene from one organism into another organism to make a functional protein.

Calculate **Suppose an mRNA molecule in the cytoplasm had 300 nucleotides. How many amino acids would be in the resulting protein?**

MAIN IDEA

Amino acids are linked to become a protein.

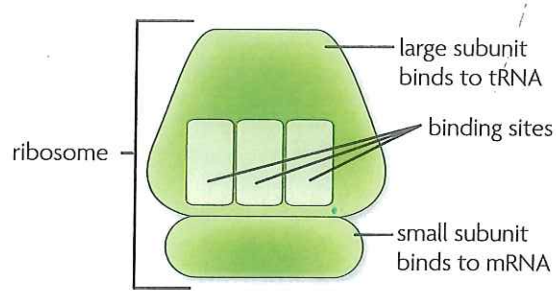
Let's take a step back to look at where we are in the process of making proteins. You know mRNA is a short-lived molecule that carries instructions from DNA in the nucleus to the cytoplasm. And you know that this mRNA message is read in sets of three nucleotides, or codons. But how does a cell actually translate a codon into an amino acid? It uses two important tools: ribosomes and tRNA molecules, as illustrated in **FIGURE 8.15.**

Recall from Chapter 3 that ribosomes are the site of protein synthesis. Ribosomes are made of a combination of rRNA and proteins, and they catalyze the reaction that forms the bonds between amino acids. Ribosomes have a large and small subunit that fit together and pull the mRNA strand through. The small subunit holds onto the mRNA strand, and the large subunit holds onto the growing protein.

The tRNA acts as a sort of adaptor between mRNA and amino acids. You would need an adaptor to plug an appliance with a three-prong plug into an outlet with only two-prong openings. Similarly, cells need tRNA to carry free-floating amino acids from the cytoplasm to the ribosome. The tRNA molecules fold up in a characteristic L shape. One end of the L is attached to a specific amino acid. The other end of the L, called the anticodon, recognizes a specific codon. An **anticodon** is a set of three nucleotides that is complementary to an mRNA codon. For example, the anticodon CCC pairs with the mRNA codon GGG.

FIGURE 8.15 TRANSLATION MACHINERY

Ribosomes The large and small ribosomal subunits pull mRNA through the ribosome, reading it one codon at a time.



tRNA In cells, tRNA forms a characteristic L shape. One end of the L has an anticodon that recognizes an mRNA codon. The other end is attached to an amino acid.

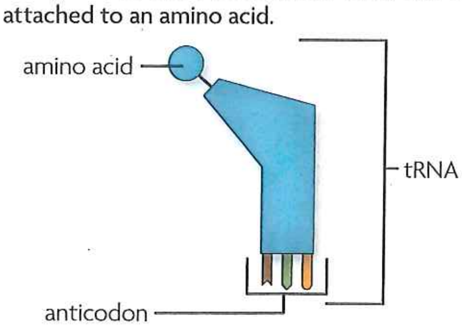
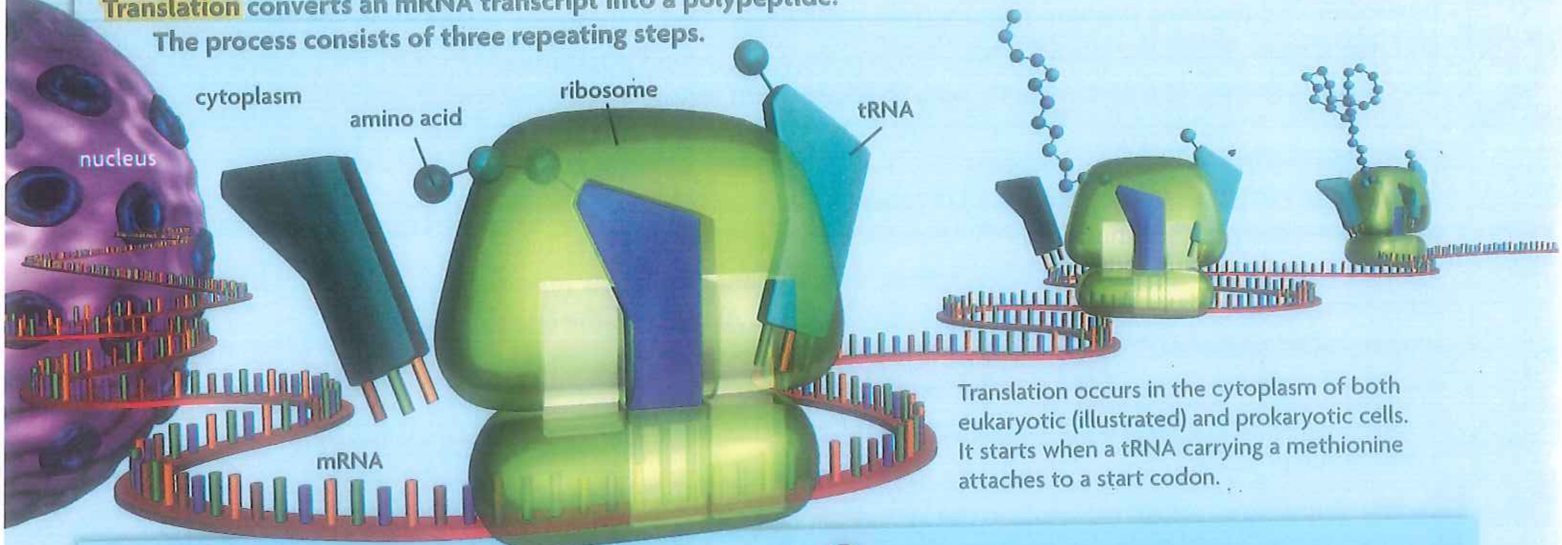


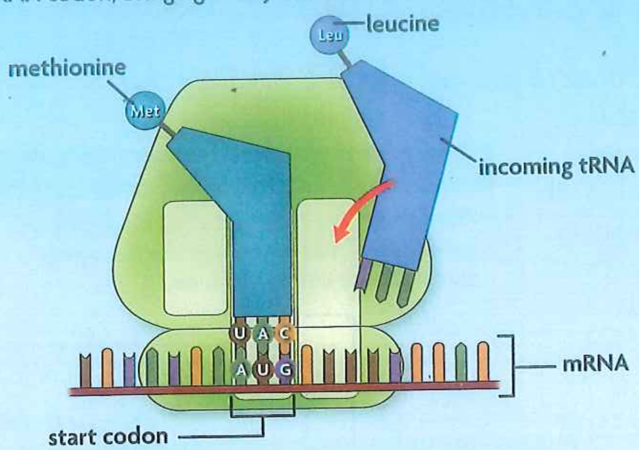
FIGURE 8.16 Translation

Translation converts an mRNA transcript into a polypeptide. The process consists of three repeating steps.

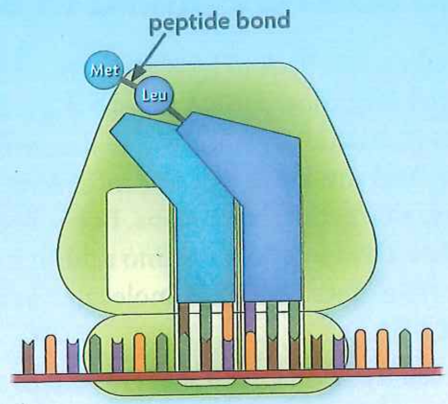


Translation occurs in the cytoplasm of both eukaryotic (illustrated) and prokaryotic cells. It starts when a tRNA carrying a methionine attaches to a start codon. . .

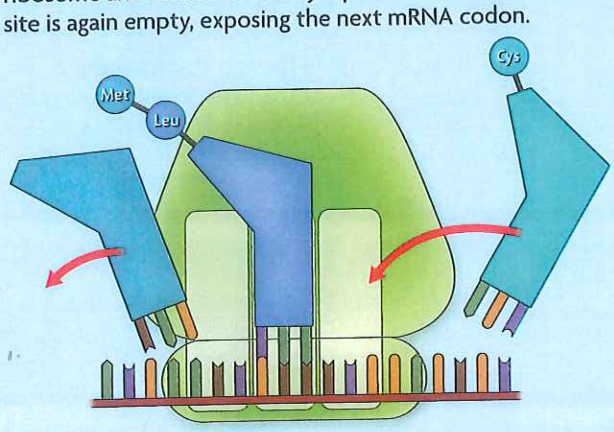
1 The exposed codon in the first site attracts a complementary tRNA bearing an amino acid. The tRNA anticodon pairs with the mRNA codon, bringing it very close to the other tRNA molecule.



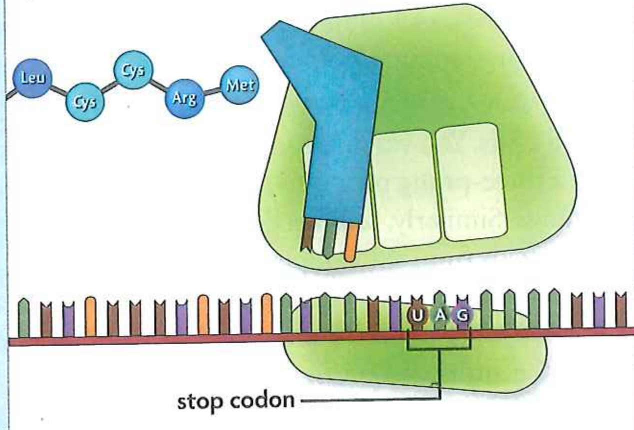
2 The ribosome forms a peptide bond between the two amino acids and breaks the bond between the first tRNA and its amino acid.



3 The ribosome pulls the mRNA strand the length of one codon. The first tRNA is shifted into the exit site, where it leaves the ribosome and returns to the cytoplasm to recharge. The first site is again empty, exposing the next mRNA codon.



The ribosome continues to translate the mRNA strand until it reaches a stop codon. Then it releases the new protein and disassembles.



CRITICAL VIEWING **The figure above shows how the first two amino acids are added to a growing protein. Draw a series of sketches to show how the next two amino acids are added.**

Translation, shown in **FIGURE 8.16**, has many steps and takes a lot of energy from a cell. It happens in the cytoplasm of both prokaryotic and eukaryotic cells. Before translation can begin, a small ribosomal subunit must bind to an mRNA strand in the cytoplasm. Next, a tRNA with methionine attached binds to the AUG start codon. This binding signals a large ribosomal subunit—which has three binding sites for tRNA molecules—to join. The ribosome pulls the mRNA strand through itself one codon at a time. As the strand moves, the start codon and its complementary tRNA molecule shift into the second site inside the large subunit. This shift leaves the first site empty, which exposes the next mRNA codon. The illustration shows the process in one ribosome, but in a cell many ribosomes may translate the same gene at the same time.

1. The exposed codon attracts a complementary tRNA molecule bearing an amino acid. The tRNA anticodon pairs with the mRNA codon. This action brings the new tRNA molecule very close to the tRNA molecule occupying the second site.
2. Next, the ribosome helps form a peptide bond between the two amino acids. The ribosome then breaks the bond between the tRNA molecule in the second site and its amino acid.
3. The ribosome pulls the mRNA strand the length of one codon. The tRNA molecule in the second site is shifted into the third site, which is the exit site. The tRNA leaves the ribosome and returns to the cytoplasm to be charged with another amino acid. The tRNA molecule that was in the first site shifts into the second site. The first site is again empty, exposing the next mRNA codon.

Another complementary tRNA molecule is attracted to the exposed mRNA codon, and the process continues. The ribosome moves down the mRNA strand, attaching new amino acids to the growing protein, until it reaches a stop codon. Then it lets go of the new protein and falls apart.

Summarize **Explain the different roles of the large and small ribosomal subunits.**

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8.5 ASSESSMENT

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REVIEWING MAIN IDEAS

1. Explain the connection between a **codon** and an amino acid. 4.b
2. Briefly describe how the process of **translation** is started. 4.a

CRITICAL THINKING

3. **Synthesize** Suppose a tRNA molecule had the **anticodon** AGU. What amino acid would it carry? 4.b
4. **Hypothesize** The DNA of eukaryotic cells has many copies of genes that code for rRNA molecules. Suggest a hypothesis to explain why a cell needs so many copies of these genes.

Connecting CONCEPTS

5. **Biochemical Reactions** Enzymes have shapes that allow them to bind to a substrate. Some types of RNA also form specific three-dimensional shapes. Why do you think RNA, but not DNA, catalyzes biochemical reactions?

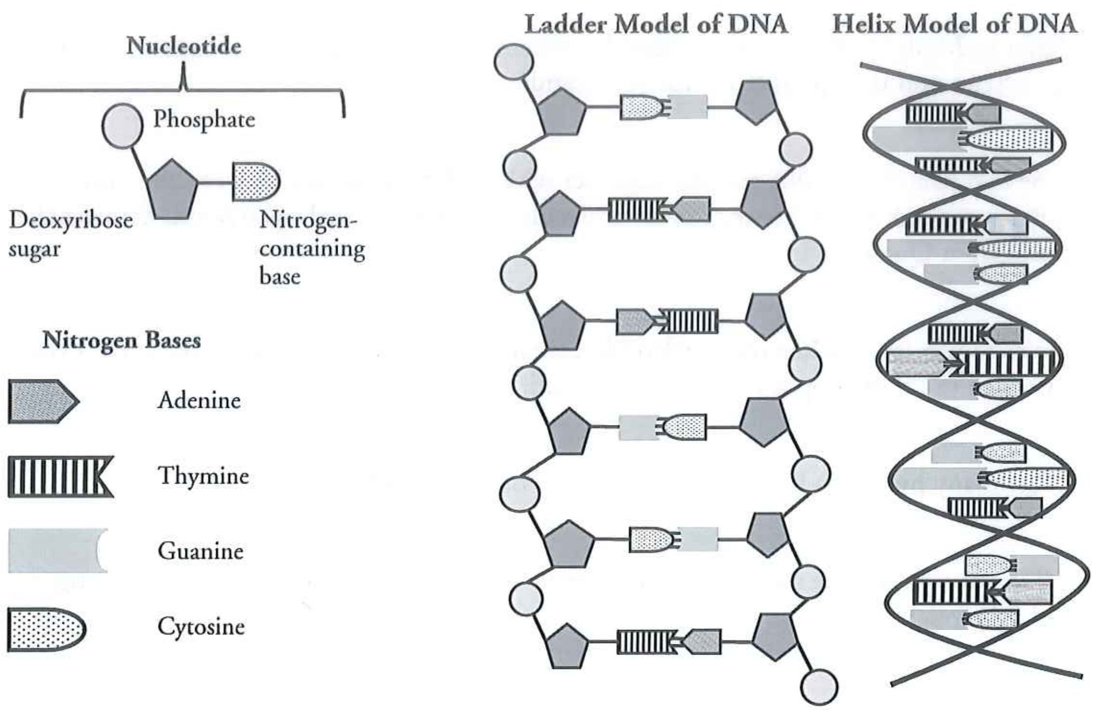
DNA Structure and Replication

How is genetic information stored and copied?

Why?

Deoxyribonucleic acid or **DNA** is the molecule of heredity. It contains the genetic blueprint for life. For organisms to grow and repair damaged cells, each cell must be capable of accurately copying itself. So how does the structure of DNA allow it to copy itself so accurately?

Model 1 – The Structure of DNA



1. Refer to the diagram in Model 1.
   a. What are the three parts of a nucleotide?

   b. What kind of sugar is found in a nucleotide?

   c. Which nucleotide component contains nitrogen?

   d. Name the four nitrogen bases shown in Model 1.

2. DNA is often drawn in a "ladder model." Locate this drawing in Model 1.
   a. Circle a single nucleotide on each side of the ladder model of DNA.

b. What part(s) of the nucleotides make up the rungs of the "ladder"?

c. What parts of the nucleotides make up the sides (backbone) of the "ladder"?

d. Look at the bottom and top of the "ladder" in Model 1. Are the rungs **parallel** (the ends of the strands match) or **antiparallel** (the ends of the strands are opposites)?

3. On the ladder model of DNA label each of the bases with the letter A, T, C or G.

4. Refer to Model 1. When one nucleotide contains adenine, what type of base is the adenine attached to on the opposite nucleotide strand?

5. The two strands of DNA are held together with **hydrogen bonds** between the nitrogen bases. These are weak bonds between polar molecules. How many hydrogen bonds connect the two bases from Question 4?

6. Refer to Model 1. When one nucleotide contains cytosine, what type of base is the cytosine attached to on the opposite nucleotide strand?

7. How many hydrogen bonds connect the two bases from Question 6?

8. With your group, use a complete sentence to write a rule for how the bases are arranged in the ladder model of DNA.

STOP

Read This!

Erwin Chargaff (1905–2002), an Austrian-American biochemist, investigated the ratio of nucleotide bases found in the DNA from a variety of organisms. From his research, as well as research by Rosalind Franklin and Maurice Wilkins, Watson and Crick developed the **complementary base-pair** rule during their race to discover the structure of DNA. The complementary base-pair rule states that adenine and thymine form pairs across two strands, and guanine and cytosine form pairs across two strands.

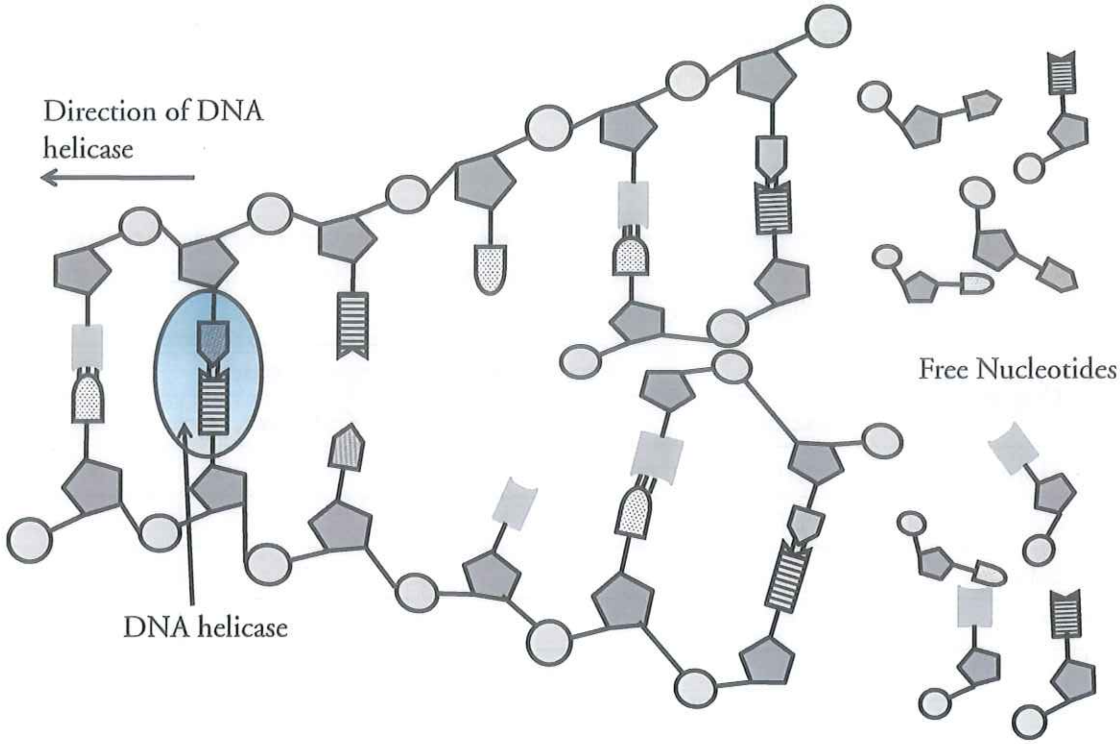
9. Fill in the **complementary** bases on the strand below according to the base-pair rule.

   A T C C A G

10. The ladder model of DNA is a simplified representation of the actual structure and shape of a DNA molecule. In reality, the strands of DNA form a **double helix**. Refer to the double helix diagram in Model 1 and describe its shape using a complete sentence.

STOP

Model 2 – DNA Replication



11. Examine Model 2. Number the steps below in order to describe the replication of DNA in a cell.

    _______ Hydrogen bonds between nucleotides form.

    _______ Hydrogen bonds between nucleotides break.

    _______ Strands of DNA separate.

    _______ Free nucleotides are attracted to exposed bases on the loose strands of DNA.

12. Locate the DNA helicase on Model 2.

    a. What type of biological molecule is DNA helicase?

    b. What is the role of DNA helicase in the replication of DNA?

13. What rule is used to join the free nucleotides to the exposed bases of the DNA?

14. This type of replication is called **semi-conservative replication**. Considering the meaning of these words (semi—half; conserve—to keep), explain why DNA replication is called semi-conservative.

15. DNA molecules can be tens of thousands of base pairs in length. Mistakes in DNA replication lead to mutations, which may or may not be harmful to an organism. How does semi-conservative replication help prevent mutations during DNA replication?

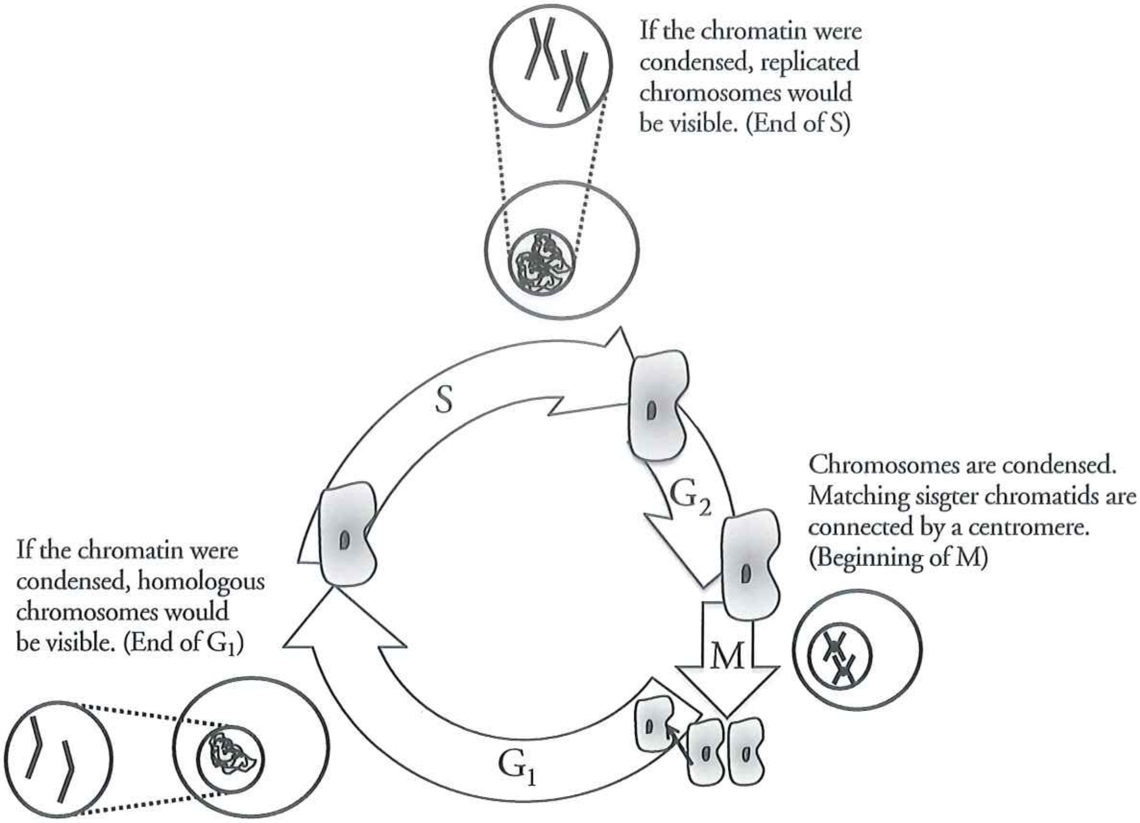
16. The proportions of the bases are consistent within a species; however they do vary between species. Using the base-pair rules, complete the following table to show the percentage of each type of base in the five different organisms.

Organism	Percentage of each type of base			
	Adenine	Guanine	Cytosine	Thymine
Human	31		19	
Cow	28	22		
Salmon			21	29
Wheat	27			
Yeast	31	19		

STOP

Extension Questions

Model 3 – Timing of DNA Replication



17. According to Model 3, what term refers to loose DNA inside of a nucleus?

18. During what part of the cell cycle is the DNA in a cell's nucleus replicated?

19. During what part of the cell cycle is the DNA in a cell condensed into chromosomes?

20. Replicated chromosomes are often illustrated as an X shape to match how they look in real life just before cell division.

    a. According to Model 3, which of the following diagrams correctly show an original set of homologous chromosomes (grey) and their sister chromatids (black)—the replicated portion?

    b. What structure holds the two sister chromatids together as they prepare for cell division?