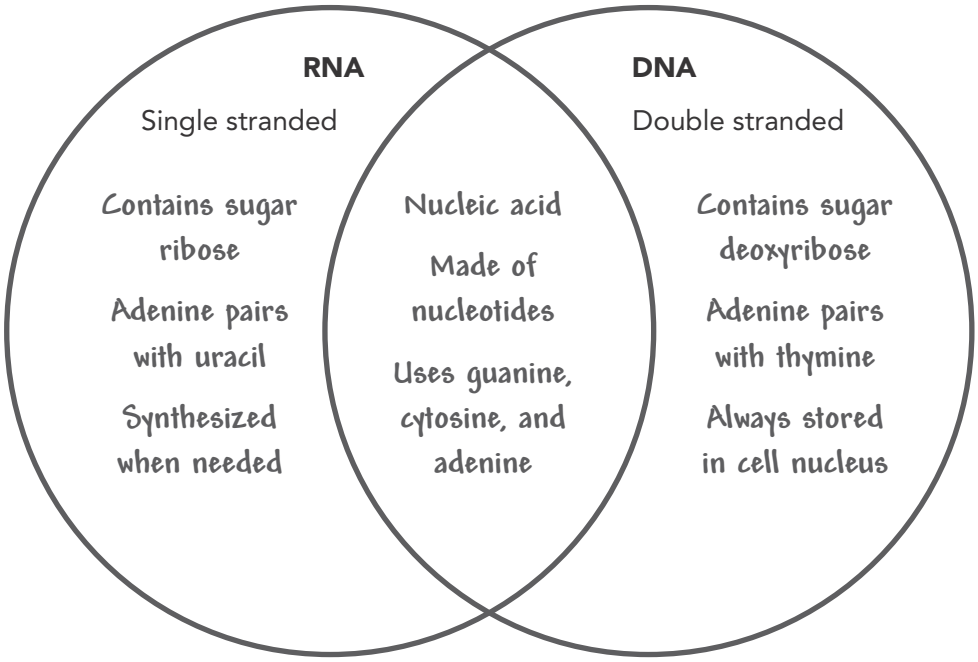
CHAPTER 14

LESSON 1

# RNA

**READING TOOL** **Compare and Contrast** As you read your textbook, identify the similarities and differences between RNA and DNA. Complete the Venn diagram to compare and contrast these molecules. A sample difference has been entered for you.
Sample answers shown.




## Lesson Summary

### The Role of RNA

**As you read, circle the answers to each Key Question. Underline any words you do not understand.**

**KEY QUESTION** *How does RNA differ from DNA?*

DNA contains a genetic code that living cells can read, understand, and express. DNA is made of just four nucleotides joined together in double-stranded molecules that can be millions of bases in length. What exactly do those bases code for, and how does the cell "read" that code? That's where RNA comes in. RNA helps to put the genetic code into action. **RNA**, like DNA, is a nucleic acid that consists of a long chain of nucleotides.

Genes contain coded DNA instructions that tell cells how to build proteins. The first step in decoding these genetic instructions is to copy part of the base sequence from DNA into RNA. RNA then uses these instructions to direct the production of proteins, which help to determine an organism's characteristics.

**BUILD Vocabulary**

**ribonucleic acid (RNA)** single-stranded nucleic acid that contains the sugar ribose

**Comparing RNA and DNA** Like DNA, RNA is made up of nucleotides. Each nucleotide consists of a 5-carbon sugar, a phosphate group, and a nitrogenous base. However, DNA and RNA differ in three important ways. RNA uses the sugar ribose instead of deoxyribose, RNA generally is single stranded, and RNA contains uracil in place of thymine. These chemical differences make it easy for enzymes in the cell to tell DNA and RNA apart.

The differences between DNA and RNA allow them to perform separate functions in the cell. The information in DNA is always around, stored safely in the cell's nucleus, where it serves as a template to make multiple RNA copies. In contrast, RNA is synthesized when the products of a particular gene are needed. RNA copies travel to the ribosomes, which then put the coded instructions into action by assembling proteins in the cytoplasm.

**Three Main Types of RNA** RNA has many roles, one of which is protein synthesis. RNA controls the assembly of amino acids into proteins. There are three main types of RNA involved in protein synthesis: messenger RNA, ribosomal RNA, and transfer RNA. Each type of RNA molecule specializes in a different aspect of the job.

***Messenger RNA (mRNA)*** Most genes encode instructions for assembling amino acids into proteins. The molecules of RNA that carry copies of these instructions from the nucleus to ribosomes in the cytoplasm are known as **messenger RNA** (mRNA).

***Ribosomal RNA (rRNA)*** Proteins are assembled on ribosomes, which are small organelles composed of two subunits. The subunits are made of several **ribosomal RNA** (rRNA) molecules and as many as 80 different proteins.

***Transfer RNA (tRNA)*** During the assembly of a protein, a third type of RNA molecule known as **transfer RNA** (tRNA) carries amino acids to the ribosome and matches them to the coded mRNA message.

## BUILD Vocabulary

**messenger RNA (mRNA)** type of RNA that carries copies of instructions for the assembly of amino acids into proteins from DNA to the rest of the cell

**ribosomal RNA (rRNA)** type of RNA that combines with proteins to form ribosomes

**transfer RNA (tRNA)** type of RNA that carries each amino acid to a ribosome during protein synthesis

**transcription** synthesis of an RNA molecule from a DNA template

**RNA polymerase** enzyme that links together the growing chain of RNA nucleotides during transcription, using a DNA strand as a template

**promoter** specific region of a gene where RNA polymerase can bind and begin transcription

**intron** sequence of DNA that is not involved in coding for a protein

**exon** expressed sequence of DNA; codes for a protein

**Prefixes** *In-* is a prefix of Latin origin that can mean "in, on, or not."

☑ **Which meaning does *in-* have in the word *intron*? Explain your answer.**

*In-* has the meaning "not" in the word *intron*. Introns are pieces of DNA that are not used to code for a protein and are cut out of pre-mRNA.

# RNA Synthesis

**KEY QUESTION** *How does the cell make RNA?*

A single DNA molecule may contain hundreds or even thousands of genes. However, only those genes being expressed are copied into RNA at any given time.

**Transcription** The process of copying a base sequence from DNA to RNA is known as **transcription**. In transcription, segments of DNA serve as templates to produce complementary RNA molecules.

**READING TOOL**

**Academic Words**

**splice** to join together

**Why do exons have to be spliced together?**

When the introns are cut out of pre-mRNA, the exons need to be joined together to form a complete mRNA strand.

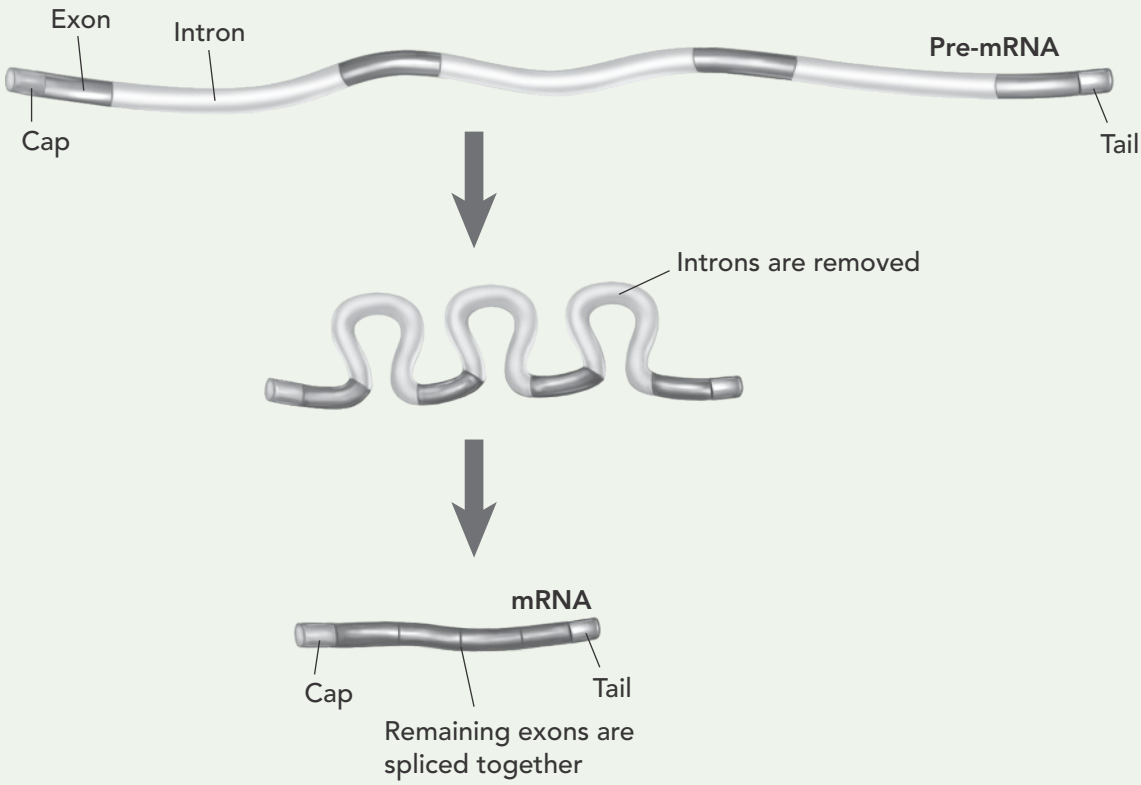
Transcription is carried out by an enzyme called **RNA polymerase**. RNA polymerase first binds to DNA and separates the DNA strands. It then uses one strand of DNA as a template to assemble nucleotides into a complementary strand of RNA. A single gene can produce hundreds, or even thousands, of RNA molecules.

**Promoters** RNA polymerase does not bind to DNA just anywhere. The enzyme binds only to **promoters**, which are regions of DNA with specific base sequences that can bind to RNA polymerase. Other regions of DNA cause transcription to stop when an RNA molecule is completed.

**RNA Editing** New RNA molecules sometimes require editing before they are ready to be read. These pre-mRNA molecules have pieces cut out of them before they can go into action. The portions that are cut out and discarded are called **introns**. The remaining pieces, known as **exons**, are then spliced back together to form the final mRNA.

## Visual Reading Tool: Introns and Exons

**1.** Use colored pencils to color the parts of pre-mRNA as it goes through the editing process to become RNA. Color the cap green, the introns blue, the exons purple, and the tail red.




**2.** How does the diagram show the difference between pre-mRNA and completed mRNA?

Pre-mRNA contains both blue introns and purple exons. mRNA contains only purple exons that have been joined together after blue introns were removed.

CHAPTER 14

LESSON 2

# Ribosomes and Protein Synthesis

**READING TOOL** **Sequence of Events** As you read your textbook, identify the steps of translation and protein synthesis. Complete the flowchart by writing the steps in the correct order. Use sequence words such as *first*, *then*, *next*, *after*, and *finally* to show the relationship between the steps. The first step has been entered for you.

Sample answers shown.

First, a ribosome attaches to the mRNA molecule in the cytoplasm.

↓

Next, the ribosome begins translating at the start codon by attracting its anticodon, which is part of the tRNA that binds the amino acid methionine.

↓

Then the ribosome binds the next codon and its anticodon, and it joins the amino acid methionine to the amino acid brought by the next tRNA with a peptide bond, starting a chain of amino acids.

↓

After that, the ribosome keeps attaching amino acids to the chain one at a time as each codon passes through the ribosome and each amino acid is delivered by the tRNA with the anticodon.

↓

Eventually, the ribosome reaches the stop codon, and the polypeptide is complete. The polypeptide and the mRNA are released from the ribosome.

↓

Finally, the polypeptide folds into its final shape or joins with other polypeptides to become a protein.

# Lesson Summary

**As you read, circle the answers to each Key Question. Underline any words you do not understand.**

## BUILD Vocabulary

**polypeptide** long chain of amino acids that makes proteins

**genetic code** collection of codons of mRNA, each of which directs the incorporation of a particular amino acid into a protein during protein synthesis

**codon** group of three nucleotide bases in mRNA that specify a particular amino acid to be incorporated onto a protein

**Root Words** The root word of the word *codon* is the word *code*.

**Why does this root word make sense?**

A codon is a single unit of genetic code that codes for an amino acid.

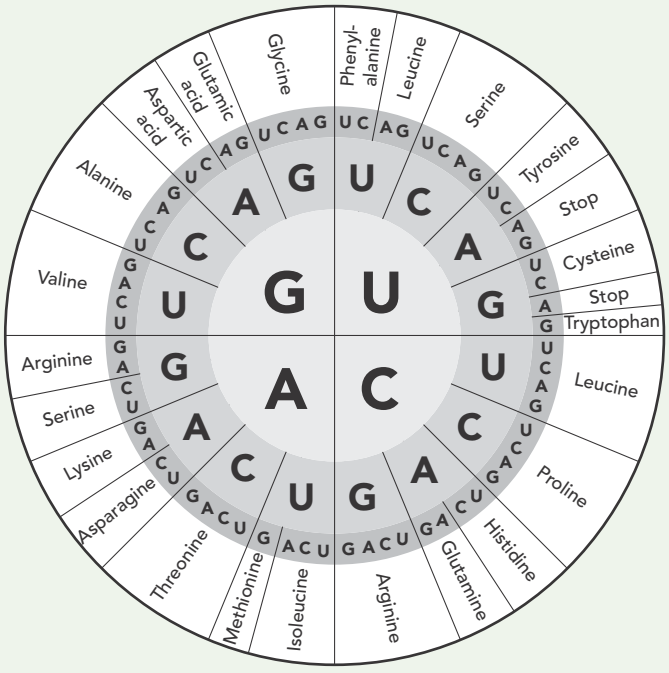
## The Genetic Code

**KEY QUESTION** *How does the genetic code work?*

Cells use the code in mRNA to build proteins, one amino acid after another. The first step in the process of decoding genetic messages is transcription, which is the copying of a nucleotide base sequence from DNA to mRNA. The next steps lead to the assembly of a protein. Proteins are made by joining amino acids together into chains called **polypeptides**. The specific order in which amino acids are joined together in a polypeptide chain determines the shape, chemical properties, and, ultimately, function of a protein.

The four bases of RNA form a kind of language with just four letters: A, C, G, and U. We call this language the genetic code. The **genetic code** is read three bases at a time. Each "word" of the code is three bases long and corresponds to a single amino acid. This three-base "word" is known as a codon. A **codon** consists of three consecutive bases that specify a single amino acid to be added to the polypeptide chain.

### Visual Reading Tool: Reading Codons




To interpret this diagram, read each codon starting at the inner circle and going toward the outer circle. For example, the codon CAC codes for the amino acid called histidine.

1. What amino acid does the codon AAU code for? asparagine
2. What three codons signal that translation should stop? UAA, UAG, UGA
3. Is it possible for a codon to code for more than one amino acid? no
4. In RNA, uracil replaced what nitrogenous base that is found in DNA? thymine

**How to Read Codons** Because there are four different bases in RNA, there are 64 possible three-base codons (4 × 4 × 4 = 64) in the genetic code. Most amino acids can be specified by more than one codon. For example, UUA, UUG, CUU, CUC, CUA, and CUG all code for leucine.

**Start and Stop Codons** The methionine codon AUG serves as the "start" codon for protein synthesis. Following the start codon, mRNA is read three bases at a time, until it reaches one of three different "stop" codons, which end translation.

# Translation

**KEY QUESTION** *What role does the ribosome play in assembling proteins?*

The sequence of bases in an mRNA molecule gives the order in which amino acids should be joined to produce a polypeptide. Once the polypeptide is complete, it then folds into its final shape or joins with other polypeptides to become a functional protein.

Ribosomes carry out the protein assembly tasks. Ribosomes use the sequence of codons in mRNA to assemble amino acids into polypeptide chains. The decoding of an mRNA message into a protein is a process known as **translation**.

**Steps in Translation** Translation begins when a ribosome attaches to an mRNA molecule in the cytoplasm. As each codon passes through the ribosome, several molecules of tRNA bring the proper amino acids into the ribosome. One at a time, the ribosome attaches these amino acids to a growing chain. Each tRNA molecule carries just one kind of amino acid. In addition, each tRNA molecule has a group of three unpaired bases that is called an **anticodon**. Each anticodon is complementary to a codon on mRNA. The polypeptide chain grows until the ribosome reaches a "stop" codon on the mRNA molecule. Then the ribosome releases both the newly synthesized polypeptide and the mRNA molecule.

**The Roles of tRNA and rRNA in Translation** The three major forms of RNA are all involved in the process of translation. The mRNA molecule carries the coded message that directs the process. tRNA molecules deliver the amino acids, enabling the ribosome to "read" the mRNA's message. Ribosomes themselves are composed of roughly 80 proteins and three or four different rRNA molecules. These rRNA molecules hold ribosomal proteins in place and carry out the chemical reactions that join amino acids together.

**READING TOOL**

**Academic Words**

**specify** To *specify* is to "identify precisely." Because each codon identifies only one amino acid, the genetic code can be accurately translated.

☑ **What is the "start" codon, and which amino acid does it specify?**

The "start" codon is AUG, which codes for methionine. It signals the ribosome to begin reading the mRNA.

**BUILD Vocabulary**

**translation** process by which the sequence of bases of an mRNA is converted into the sequence of amino acids of a protein

**anticodon** group of three bases on a tRNA molecule that are complementary to the three bases of a codon of mRNA

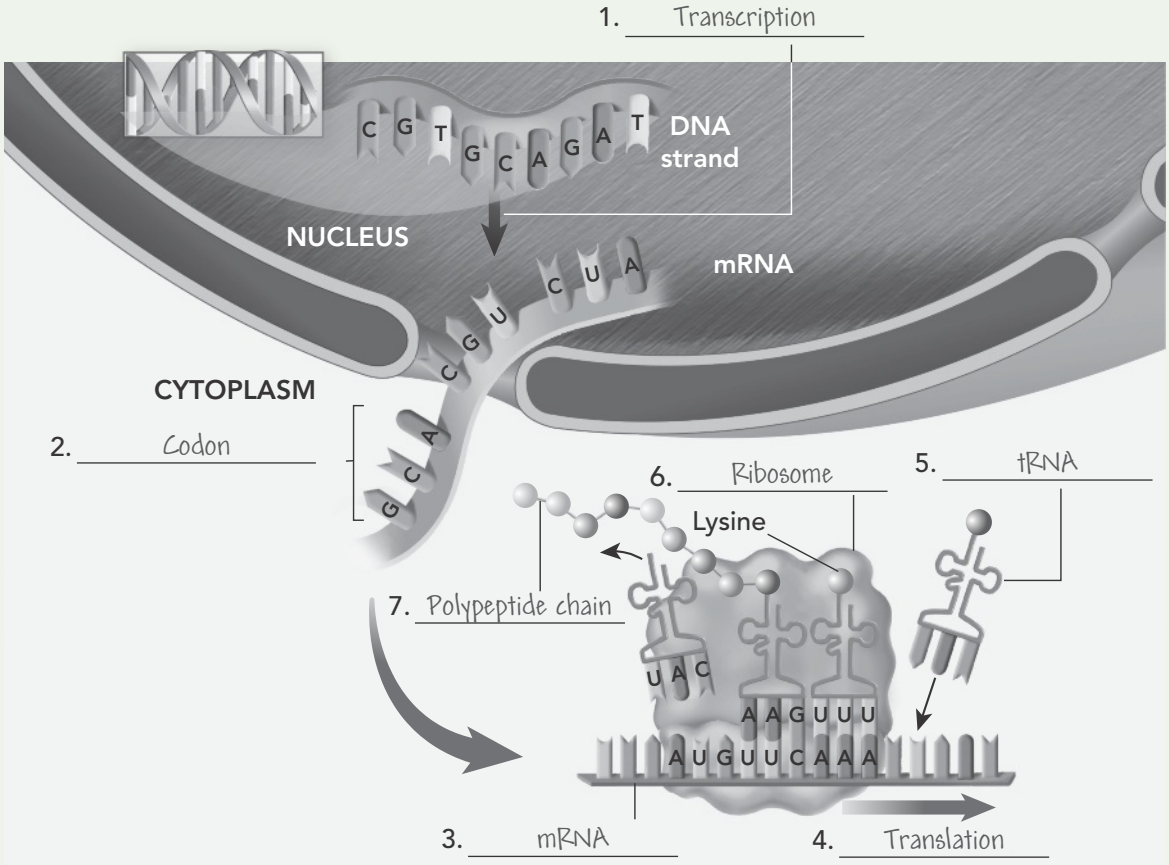
**Multiple Meanings** The word *translation* is also used to describe the process of changing speech or text from one language to another.

☑ **How is the translation of mRNA like the translation of a language?**

Translating language requires a translator who understands both languages. Translating mRNA requires ribosomes, which can "read" the 4-letter "language" of mRNA and "translate" it into chains of amino acids used to build proteins.

**Visual Reading Tool: Transcription and Translation**

Fill in the missing labels on the diagram of protein synthesis.




# Molecular Genetics

**READING TOOL**

**Make Connections** In this lesson and the previous one, you learned about the related processes of RNA transcription and translation.

**How is transcription related to protein translation?**

Transcription is the process that generates mRNA, which is read by the ribosome and turned into a protein during translation.

**KEY QUESTION** *How does molecular biology relate to genetics?*

Most genes contain nothing more than instructions for assembling proteins. Many proteins are enzymes, which catalyze and regulate chemical reactions, thereby affecting the expression of genetic traits. In short, proteins are microscopic tools, each specifically designed to build or operate a component of a living cell.

Once scientists explained the genetic code, a new scientific field called molecular biology was established. Molecular biologists seek to understand living organisms by studying them at the molecular level, using molecules like DNA and RNA. Molecular biology provides a way to understand the links between genes and the characteristics they influence.

One of the most interesting discoveries of molecular biology is the near-universal nature of the genetic code. Although some organisms show slight variations in the amino acids assigned to particular codons, the code is always read three bases at a time, is always read in the same direction, and is always translated on ribosomes composed of RNA and protein.

CHAPTER 14

LESSON 3

# Gene Regulation and Expression

**READING TOOL** **Main Ideas and Details** As you read your textbook, identify the main ideas and details or evidence that support the main ideas. Use the lesson headings to organize the main ideas and details. Record your work in the table. Two examples are entered for you.

Sample answers shown.

| Heading | Main Idea | Details/Evidence |
|---|---|---|
| **Prokaryotic Gene Regulation** | | |
| The *Lac* Operon | The *lac* operon controls the production of proteins needed for *E. coli* to use lactose for food. | When the bacterium is in an environment with lactose as a food source, the *lac* operon genes are transcribed. |
| Promoters and Operators<br>• The *lac* repressor blocks transcription<br>• Lactose turns the operon "on" | Genes are expressed when RNA polymerase can bind to mRNA at the promoter, and they are not expressed when a repressor binds to the mRNA at the operator. | When lactose is not present, the *lac* repressor binds to the operator region so that *lac* genes are not transcribed. |
| **Eukaryotic Gene Regulation** | | |
| Transcription Factors | Transcription factors control gene expression by binding DNA sequences in the regulatory regions of genes. | Some transcription factors block access to genes so they are not expressed. |
| Cell Specialization | In multicellular organisms, cells must be differentiated and specialized. | Genes are expressed differently in cells depending on what part of the organism the cells are in. |
| **Genetic Control of Development** | | |
| Homeotic Genes | Homeotic genes are master control genes that regulate patterns of development and differentiation in different parts of the body. | Hox genes in fruit flies determine the identities of segments of a fly's body. |
| Epigenetics | Epigenetic markers influence patterns of gene expression over time by controlling chromatin density. | Markers that cause chromatin to condense prevent genes from being expressed. |
| Environmental Influences | Environmental factors can affect whether or how a gene is expressed. | Temperature affects the expression of the gene for fur color in Himalayan rabbits. |

# Lesson Summary

## Prokaryotic Gene Regulation

**KEY QUESTION** *How are prokaryotic genes regulated?*

By regulating gene expression, bacteria can respond to changes in their environment. DNA-binding proteins in prokaryotes regulate genes by controlling transcription. Some of these regulatory proteins switch genes on, while others turn genes off.

How does an organism know when to turn a gene on or off? *E. coli* provides us with an example. Three genes must be turned on together before the bacterium can break apart lactose, a type of sugar, for food. Because the three genes are "operated" together, they are called the *lac* operon. An **operon** is a group of genes that are regulated together.

**The *Lac* Operon** To use lactose for food, the bacterium must have the proteins coded for by the genes of the *lac* operon. The bacterium seems to "know" when the products of the *lac* operon genes are needed and when they're not needed. For example, if the bacterium grows in a medium where lactose is the only food source, the genes are transcribed to produce the proteins. If the environment changes to another food source, then the genes are not transcribed.

**Promoters and Operators** On one side of the operon's three genes, there are two regulatory regions. The first is a promoter (P), which is a site where RNA polymerase can bind to begin transcription. The other region is called the **operator** (O). The O site is where a DNA-binding protein known as the *lac* repressor can bind to DNA.

***The* Lac *Repressor Blocks Transcription*** When lactose is not present, the *lac* repressor binds to the O region and RNA polymerase cannot reach the *lac* genes to begin transcription. The binding of the repressor protein switches the operon "off" by preventing the transcription of its genes.

***Lactose Turns the Operon "On"*** When lactose is present, some of it attaches to the *lac* repressor and causes it to fall off the operator. RNA polymerase can bind to the promoter and transcribe the genes of the operon. As a result, in the presence of lactose, the operon is automatically switched on. Many other prokaryotic genes are switched on or off by similar mechanisms.

**As you read, circle the answers to each Key Question. Underline any words you do not understand.**

### BUILD Vocabulary

**operon** in prokaryotes, a group of adjacent genes that share a common operator and promoter and are transcribed into a single mRNA

**operator** short DNA region, adjacent to the promoter of a prokaryotic operon, that binds repressor proteins responsible for controlling the rate of transcription of the operon

**Root Words** The Latin root word *oper* means "work." Similar words include *operate* or *operator*.

**How does the operator region of DNA work to regulate gene expression?**

When a repressor is bound to the operator region, the promoter is blocked and genetic material cannot be transcribed. When the operator region is empty, RNA polymerase can bind to the promoter and transcription can occur.

# Eukaryotic Gene Regulation

**KEY QUESTION** *How are genes regulated in eukaryotic cells?*

The general principles of gene expression in prokaryotes also apply to eukaryotes, but the regulation of many eukaryotic genes is much more complex.

**Transcription Factors** DNA-binding proteins known as transcription factors play an important part in regulating gene expression. By binding DNA sequences in the regulatory regions of eukaryotic genes, transcription factors control gene expression. A transcription factor can activate scores of genes at once, thereby dramatically affecting patterns of gene expression. Eukaryotic gene expression can also be regulated by many other factors.

**Cell Specialization** Gene regulation in eukaryotes is more complex than in prokaryotes because of the way in which genes are expressed in a multicellular organism. Cell differentiation requires genetic specialization, yet most of the cells in a multicellular organism carry the same DNA in their nucleus. Complex gene regulation in eukaryotes makes it possible for cells to be differentiated and specialized. Gene regulation also allows multicellular organisms to reproduce. Complex changes in gene expression allow the single cell of a new organism to develop into a functioning multicelluar organism.

# Genetic Control of Development

**KEY QUESTION** *What controls the development of cells and tissues in multicellular organisms?*

The activation of genes in different parts of an embryo cause cells to differentiate. The process of **differentiation** gives rise to specialized tissues and organs.

**Homeotic Genes** A set of master control genes, known as **homeotic genes**, regulates organs that develop in specific parts of the body. Homeotic genes share a very similar 180-base DNA sequence, the *homeobox*. **Homeobox genes** code for transcription factors that activate other genes that are important in cell development and differentiation. In flies, homeobox genes known as **Hox genes** are located side by side in a single cluster. Hox genes determine the identities of each segment of a fly's body. They are arranged in the order in which they are expressed, from anterior to posterior. Hox genes exist in the DNA of other animals, including humans. These genes are also arranged from head to tail, and they tell the cells of the body how to differentiate as the body grows. This means that nearly all animals share the same basic tools for building the different parts of the body.

## BUILD Vocabulary

**differentiation** process in which cells become specialized in structure and function

**homeotic gene** class of regulatory genes that determine the identity of body parts and regions in an animal embryo. Mutations in these genes can transform one body part into another.

**homeobox genes** genes that code for transcription factors that activate other genes that are important in cell development and differentiation

**Hox gene** group of homeotic genes clustered together that determine the head-to-tail identity of body parts in animals. All Hox genes contain the homeobox DNA sequence.

**Word Origins** The word part *homeo* comes from the Latin and Greek part *homio*, meaning "similar to" or "the same kind." Homeobox genes are a group of similar genes that regulate specific structures.

☑ **How are Hox genes, a type of homeotic gene, similar across species?**

Hox genes are homeotic genes found in nearly all animals that are always arranged from head to tail.

**READING TOOL**

**Make Connections** The prefix *epi-* means "over." Epigenetic changes, such as the addition of markers, occur *above*, or *over*, the level of the genome. ☑ **If epigenetic changes take place above the level of the genome, what would be an example of a change at the level of the genome?**

A change to the DNA base sequence would be at the level of the genome.

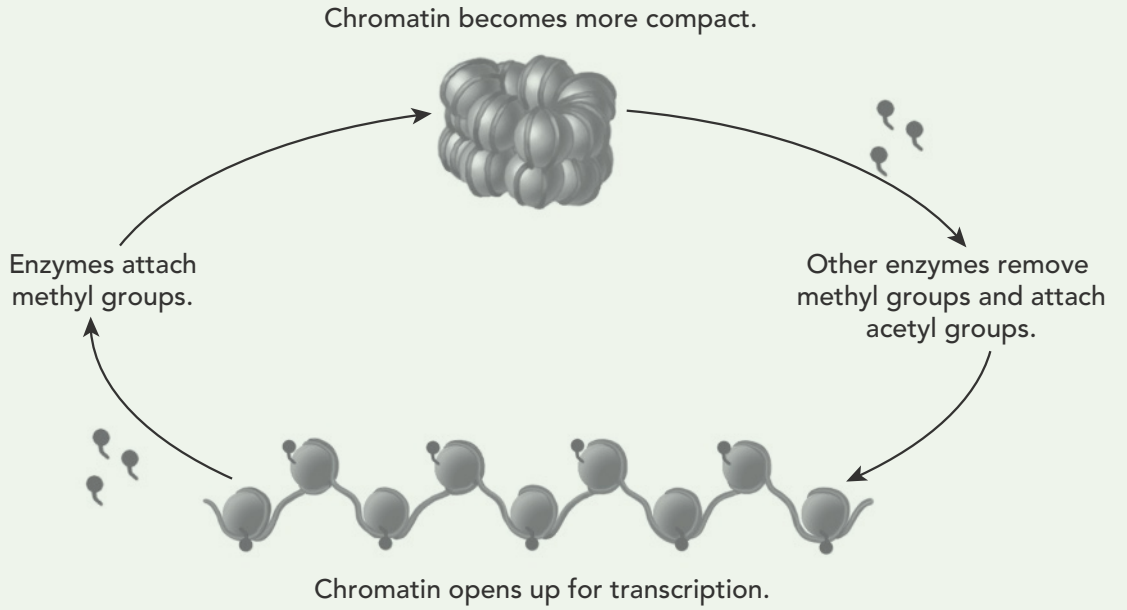
Common patterns of genetic control exist because all these genes have descended from the genes of common ancestors. Master control genes are like switches that trigger particular patterns of development and differentiation in cells and tissues. The details can vary from one organism to another, but the switches are nearly identical.

**Epigenetics** In places where chromatin is tightly packed, gene expression is blocked. In regions where chromatin is opened up, gene expression is enhanced. Cells can regulate the state of chromatin by enzymes that attach chemical groups to DNA and to histone proteins.

These chemical marks on chromatin are epigenetic, or above the level of the genome. Epigenetic marks do not change DNA base sequences. Instead, they influence patterns of gene expression over long periods of time.

**Environmental Influences** In prokaryotes and eukaryotes, environmental factors can regulate gene expression. The environment can often influence how and when epigenetic marks are attached to chromatin. Environmental factors can also directly affect the expression of other genes.

**Visual Reading Tool: Effect of Chemical Marks on Gene Expression**




**1.** Why are genes contained in compact chromatin not expressed?

When chromatin is compact, the enzymes necessary for gene expression cannot attach to start transcription.

**2.** What epigenetic marker changes cause chromatin to open up?

Chromatin opens up when enzymes in the cell remove methyl groups from the DNA and attach acetyl groups.

CHAPTER 14

LESSON 4

# Mutations

**READING TOOL** **Cause and Effect** As you read your textbook, find a brief description of each cause, or mutation, provided. Then identify its possible effect(s). Record your work in the table. An example is entered for you.

Sample answers shown.

| Mutation (Cause) | Description | Effect(s) |
|---|---|---|
| Silent Mutation | A changed codon of mRNA results in the same amino acid. | None; the amino acid sequence is unchanged and the protein is normal. |
| Missense Mutation | A changed codon of mRNA results in a different amino acid. | The amino acid sequence is changed, potentially altering the protein. |
| Nonsense Mutation | The mutation codes for a stop codon. | Translation stops before the protein is finished; a defective protein may be produced. |
| Frameshift Mutation | A base is inserted into or deleted from the DNA sequence. | The reading frame shifts, changing every amino acid from the mutation onward; the protein may be altered so that it cannot function. |

# Lesson Summary

As you read, circle the answers to each Key Question. Underline any words you do not understand.

## BUILD Vocabulary

**mutation** change in the genetic material of a cell

**point mutation** gene mutation in which a single base pair in DNA has been changed

**frameshift mutation** mutation that shifts the "reading frame" of the genetic message by inserting or deleting a nucleotide

**Word Origins** The word *mutation* comes from the Latin word *mutare*, meaning "to change." ☑ **Which types of point mutations typically cause the most significant changes?**

Frameshift mutations can change a protein so much that it cannot carry out its normal function.

## Types of Mutations

**KEY QUESTION** *In what ways do mutations change genetic information?*

When cells make mistakes in copying their own DNA, the resulting variations are called **mutations**. Mutations are heritable changes in genetic information. Mutations can involve changes in the sequence of nucleotides in DNA or changes in the number or structure of chromosomes.

**Point Mutations** Mutations that change a single base pair are **point mutations**. Point mutations usually involve a substitution, in which one base is changed to a different base. Substitutions usually affect no more than a single amino acid, and sometimes have no effect at all. Mutations that don't affect amino acid sequence are known as *silent mutations*. Mutations that change the amino acid specified by a codon can be more significant and are called *missense mutations*.

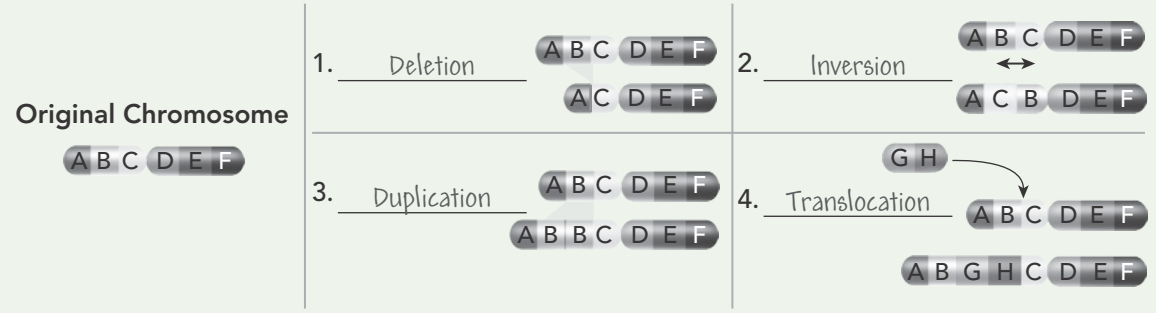
If a mutation changes an mRNA codon to result in a stop codon, it is known as a *nonsense mutation* because it causes translation to stop before the protein is finished. This can result in the production of a defective protein.

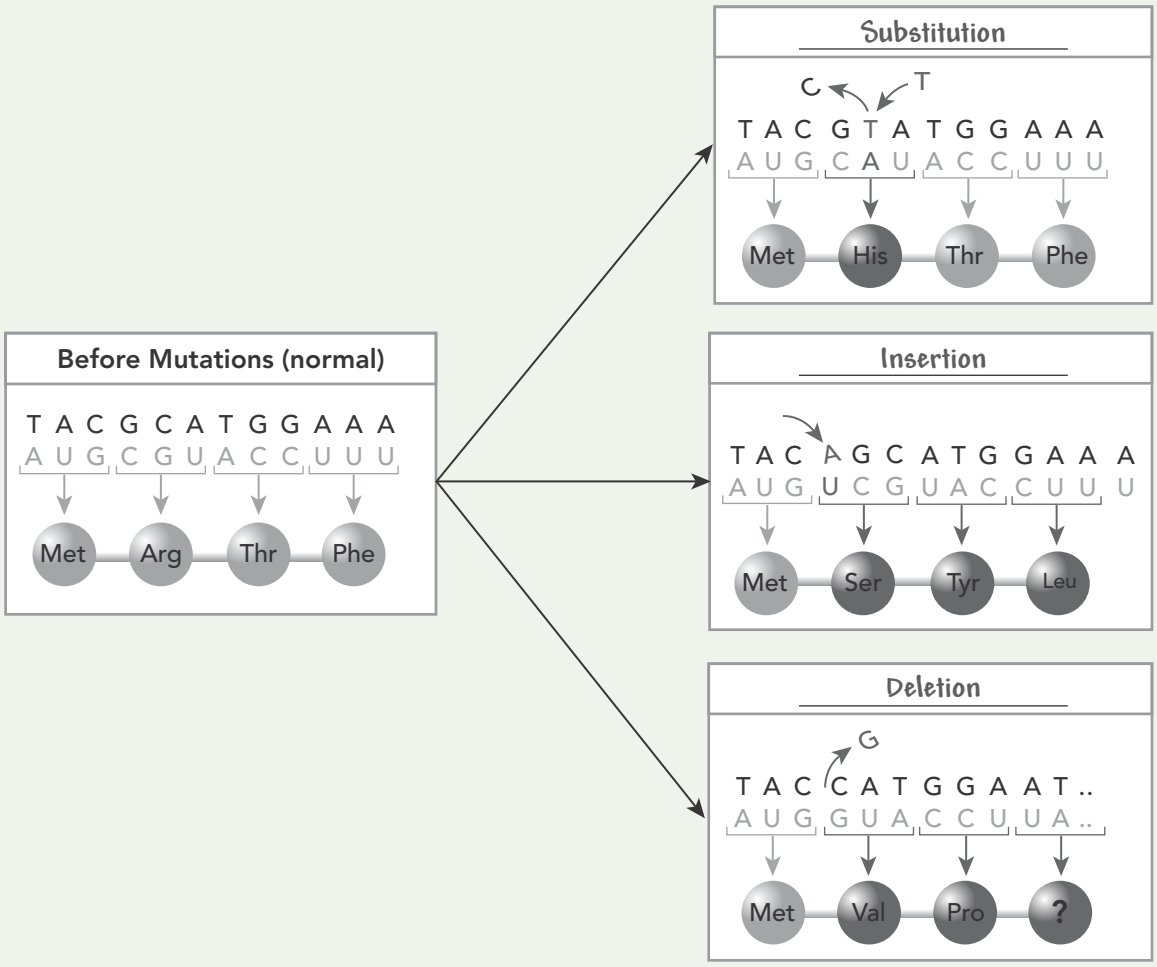
**Insertions and Deletions** Mutations in which one base or many bases are inserted or removed from the DNA sequence are called insertions and deletions. Insertions and deletions are also called **frameshift mutations** because they shift the "reading frame" of the genetic message. Frameshift mutations can change every amino acid that follows the point of the mutation. They can alter a protein so much that it is unable to perform its normal functions.

**Chromosomal Mutations** Chromosomal mutations involve changes in the number or structure of chromosomes. These mutations can change the location of genes on chromosomes and can even change the number of copies of some genes. There are four types of chromosomal mutations: deletion, duplication, inversion, and translocation. Deletion involves the loss of all or part of a chromosome, duplication produces an extra copy of all or part of a chromosome, and inversion reverses the direction of parts of a chromosome. Translocation occurs when part of one chromosome breaks off and attaches to another.

## Visual Reading Tool: Mutations

On the diagrams below, label each type of mutation.




**5.** Numbers 1–4 are known as what type of mutation? Circle your answer.

(chromosomal) point missense

**6.** The bottom figure is known as what type of mutation? Circle your answer.

chromosomal nonsense (point)

**7.** What is the difference between point mutations and chromosomal mutations?

Point mutations change a single base pair, while chromosomal mutations change entire pieces of chromosomes. Point mutations generally affect one protein, while chromosomal mutations can affect entire gene sequences.

## BUILD Vocabulary

**mutagen** chemical or physical agent in the environment that interacts with DNA and may cause a mutation

**polyploidy** condition in which an organism has extra sets of chromosomes

**Suffixes** The suffix *-gen* means "producing." ☑ **How does a mutagen produce a mutation?**

A mutagen interacts with DNA and damages it, causing mutations.

# Effects of Mutations

**KEY QUESTION** *How do mutations affect genes?*

Genetic material can be altered by natural events or by artificial means. The resulting mutations may or may not affect an organism. Some mutations that affect individual organisms can also affect a species or even an entire ecosystem.

Many mutations are produced by errors in genetic processes. DNA replication results in an incorrect base roughly once in every 10 million bases. But small changes in genes can gradually accumulate over time.

## Mutagens

Some mutations arise from **mutagens**, chemical or physical agents in the environment. If these agents interact with DNA, they can produce mutations at high rates. Cells can sometimes repair the damage, but when they cannot, the DNA base sequence changes permanently.

## Harmful and Helpful Mutations

The effects of mutations on genes vary widely. Some have little or no effect, some produce beneficial variations, and some negatively disrupt gene function. Many mutations are neutral; they have little or no effect on the expression of genes or the function of the proteins for which they code. Whether a mutation is negative or beneficial depends on how its DNA changes relative to the organism's situation. Mutations are often thought of as negative, since they can disrupt the normal function of genes. However, without mutations, organisms could not evolve. Mutations are the source of genetic variability in a species.

### *Harmful Effects*

Some of the most harmful mutations are those that dramatically change protein structure or gene activity. The defective proteins produced by these mutations can disrupt normal biological activities, and result in genetic disorders. Some cancers, for example, are the product of mutations that cause the uncontrolled growth of cells.

### *Helpful Effects*

Mutations often produce proteins with new or altered functions that can be useful to organisms in different or changing environments. Plant and animal breeders often make use of "good" mutations. For example, when a complete set of chromosomes fails to separate during meiosis, the gametes that result may produce organisms with extra sets of chromosomes. The condition in which an organism has extra sets of chromosomes is called **polyploidy**. Polyploid plants are often larger and stronger than diploid plants. Important crops have been produced this way.

# 14 Chapter Review

## Review Vocabulary

*Choose the letter of the best answer.*

**1.** The molecule that carries amino acids to the ribosome is called

(A.) transfer RNA.

B. ribosomal RNA.

C. messenger RNA.

**2.** Insertions and deletions are also known as

A. silent mutations.

B. nonsense mutations.

(C.) frameshift mutations.

*Match the vocabulary term to its definition.*

**3.** c the process of decoding an mRNA message into a protein

**4.** a the process of copying a base sequence from DNA to RNA

**5.** b the process by which variations are introduced into DNA

a. transcription

b. mutation

c. translation

## Review Key Questions

*Provide evidence and details to support your answers.*

**6.** How are both DNA and RNA involved in the process of protein synthesis?

For protein synthesis to occur, mRNA must be transcribed from DNA. mRNA is then translated by the ribosomes, which use the codons of mRNA to assemble the polypeptides that make up proteins.

**7.** Describe gene regulation in prokaryotes.

Genes are turned "on" and "off" in the regulatory regions. When the products of a gene are not needed, a repressor binds to the operator and prevents transcription from taking place. When the products of the gene are needed, the repressor detaches from the operator so that RNA polymerase can bind to the promoter and transcription can take place.

**8.** How can mutations affect organisms?

Mutations can be helpful, be harmful, or have no effect. The majority of mutations have little or no effect. Some mutations, such as polyploidy in plants, benefit the organism. Other mutations damage DNA and can result in disorders, such as uncontrolled cell growth in cancer.