# Section 2.2
# Protein Synthesis

## Section Overview

DNA codes for amino acids, which are the building blocks of proteins. Proteins, in turn, have a number of functions including support, structure, movement, transport, communication, and defense.

In this section you will learn about the two major processes that occur to synthesize protein-transcription and translation. With all the DNA coding going on (at very fast rates) it's amazing problems don't arise once in a while. They do—in the form of genetic disorders or mutations. This section will also deal with genetic mutations.

Have you explored the Mader Online Web site? If you have Internet access go check it out on the *Biology 12 Web site*. It contains numerous simulations of difficult concepts such as an animation relating to feedback inhibition in the metabolic pathway.

# Lesson 2.2A
# Protein Synthesis, Part 1: Transcription

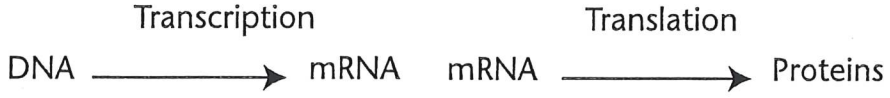
## Overview

The structure of the DNA molecule is the same in every living organism. All of life, in its infinite variety, from slime mould to the extinct Stegosaurus, is constructed from the same basic information contained in each cell. How is it possible that a molecule consisting of only six parts can provide all the information needed to produce millions of species of life?

You have already learned about the structure of DNA and that it is made up of a long series of nucleotides. These nucleotides are made up of a deoxyribose sugar, a phosphate group, and a nitrogenous base (A, T, C, or G)—the six parts of the DNA molecule. The bases are paired (A with T and C with G) and joined by hydrogen bonds, and the sugars and phosphate groups form the backbone of DNA's three-dimensional double helix.

DNA codes for amino acids, which are the building blocks of proteins. Proteins, in turn, have a number of functions, including support, structure, movement, transport, communication, and immune defense. Protein-containing structures include hair, nails, hooves, horns, hormones, antibodies, blood proteins, and enzymes.

In the next two lessons you will investigate protein synthesis, the complex process of creating a protein from a **DNA sequence**. Two major processes are involved:




In this lesson you will learn about the process of **transcription**, and begin to focus on how the information contained in DNA is processed to form a final product—a protein.

## Guided Practice 2.2A 2
## DNA vs. RNA

Before you continue with this lesson, complete the following guided practice to briefly review the differences between DNA and RNA.

Fill in the blanks in the following DNA vs. RNA table. Before proceeding with the lesson, use the Answer key to check your answers.

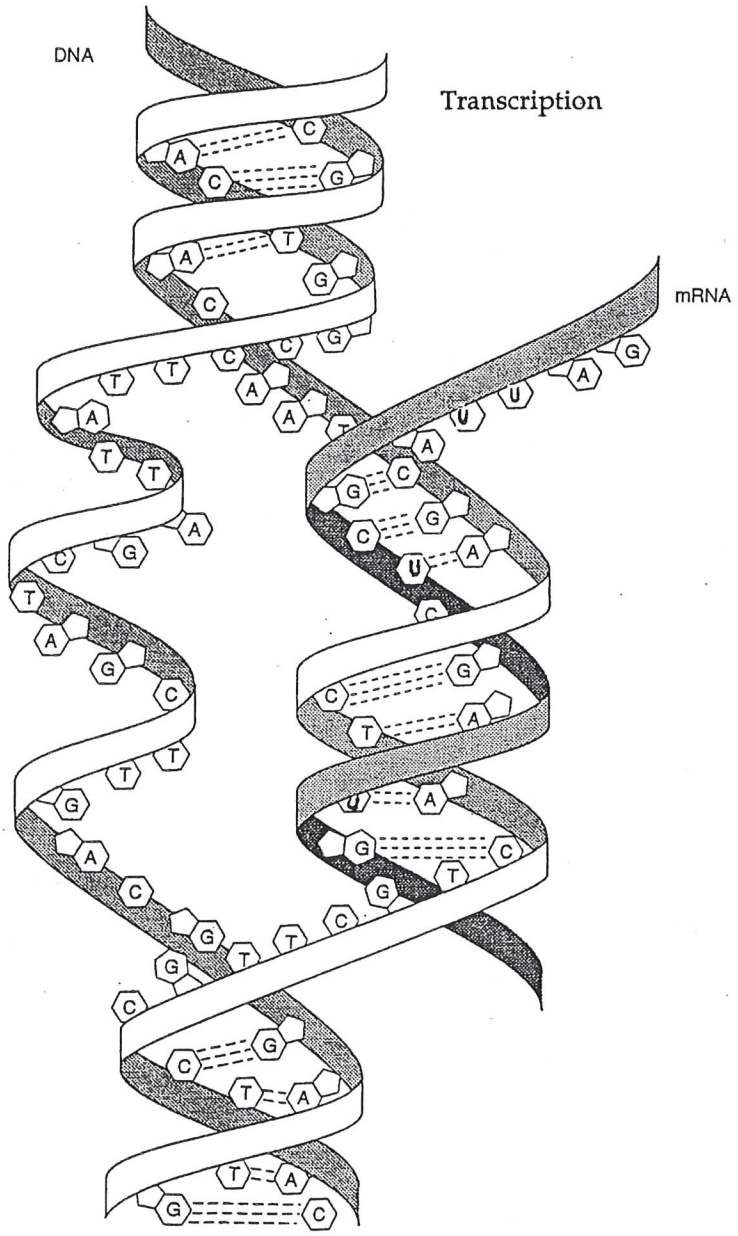
| | DNA | RNA |
|---|---|---|
| Shape of molecule | double helix | |
| Location in the cell: | | nucleus and cytoplasm |
| The four bases are: | | |
| The sugar is: | | |
| Created by: | | transcription |
| Enzyme(s) involved: | | RNA polymerase |

## mRNA Transcription

DNA is housed in the nucleus of a cell. In order for the information contained in DNA to reach the ribosomes (the site of protein synthesis) in the cell's cytoplasm, this information must first exit the nucleus. This is the purpose of **messenger RNA** (mRNA). In the same way a manager might dictate a letter to a secretary, transcription is the process by which the DNA code is dictated to another molecule (mRNA) that will then deliver its message into the cytoplasm.

Although there are only four nitrogenous bases, they can be arranged in countless different DNA sequences. It's this infinite variety of sequences that gives rise to the enormous diversity of life. All organisms contain the same complementary base pairs, but they are arranged in different ways.

One specific sequence of bases is termed a **promoter** region. To begin transcription, an enzyme (**RNA polymerase**) binds to a promoter region and begins to open up the DNA double helix, detaching base pairs and allowing complementary base re-pairing between one DNA strand and RNA nucleotides. RNA polymerase also connects mRNA nucleotides to form a single strand of mRNA. Recall that mRNA contains the base uracil in place of thymine. When a gene (a section of DNA) is transcribed, mRNA is created. mRNA will then direct the production of a certain protein. Each gene therefore codes for one specific protein.




*Transcription of mRNA from DNA. One DNA strand serves as the template for mRNA production; the other DNA strand does not participate and is termed inactive at this transcription site. The inactive strand may, however, be actively transcribing mRNA elsewhere along its length.*

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**Note that although only mRNA is discussed here, all three types of RNA (transfer or tRNA, and ribosomal or rRNA are the other types) are formed by transcription.**

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If you have access to the Internet, go to the *Biology 12 Web site* Lesson 2.2A Protein Synthesis, Part 1: Transcription to view an animation of this process. This animation will help you visualize transcription. Stop the animation when the tRNA discussion begins. You can revisit the site after the next lesson and watch the rest of the protein synthesis process.

Since the newly transcribed mRNA strand will eventually code for the production of a protein, the sequence of bases in mRNA is extremely important. Every three bases along the mRNA strand will provide the code for one amino acid. These three-base groupings are triplet **codons**. For example, the bases A-A-G will code for the amino acid lysine. In total there are 64 possible different three-base combinations (codons), but they only code for 20 amino acids.

**Three-letter codons of messenger RNA, and the amino acids specified by the codons**

| | | | |
|---|---|---|---|
| AAU, AAC — Asparagine | CAU, CAC — Histidine | GAU, GAC — Asparatic acid | UAU, UAC — Tyrosine |
| AAA, AAG — Lysine | CAA, CAG — Glutamine | GAA, GAG — Glutamic acid | UAA, UAG — Stop |
| ACU, ACC, ACA, ACG — Threonine | CCU, CCC, CCA, CCG — Proline | GCU, GCC, GCA, GCG — Alanine | UCU, UCC, UCA, UCG — Serine |
| AGU, AGC — Serine<br>AGA, AGG — Arginine | CGU, CGC, CGA, CGG — Arginine | GGU, GGC, GGA, GGG — Glycine | UGU, UGC — Cysteine<br>UGA — Stop<br>UGG — Tryptophan |
| AUU, AUC, AUA — Isoleucine<br>AUG — Methionine | CUU, CUC, CUA, CUG — Leucine | GUU, GUC, GUA, GUG — Valine | UUU, UUC — Phenylalanine<br>UUA, UUG — Leucine |

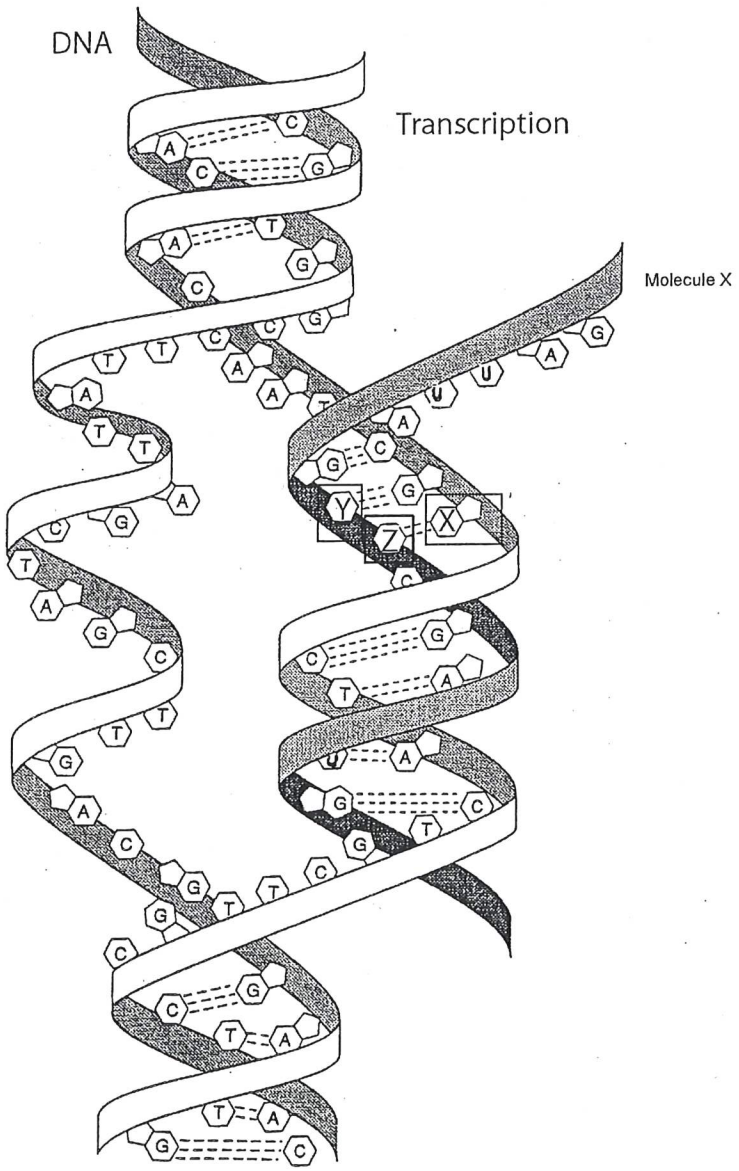
*Codons and the Amino Acids they specify.*

Notice that most amino acids have more than one codon associated with them, but some have six! Why have more than one codon to code for an amino acid? The answer may be that this protects the protein being formed. Any mutation that causes the last base in a codon to alter will still produce the same amino acid, and therefore still produce the correct protein.

## Guided Practice 2.2A 3
# Transcription Self-check

To be sure you understand protein synthesis so far, try the following quiz. This will not be submitted for marks, but it will give you some instant feedback!

Use the following diagram to answer questions 1 to 4.



1. The process shown above is:
   A. replication
   B. transcription
   C. transformation
   D. denaturation

2. Molecule X contains:
   A. deoxyribose sugar
   B. hydrogen bonds
   C. thymine and uracil
   D. uracil and adenine

3. What joins the structure in box Z with the structure in box X?
   A. complementary base bonds
   B. covalent bonds
   C. hydrogen bonds
   D. polymerase bonds

4. The enzyme involved in the process shown is:
   A. RNA ligase
   B. DNA transcriptase
   C. RNA polymerase
   D. DNA replicase

5. What is the most likely result of a mutation in the last base of a codon?
   A. The codon will specify the same amino acid as before.
   B. Mitosis cannot occur and the cell will be unable to divide.
   C. Transcription will be terminated and mRNA will degenerate.
   D. A different protein will be synthesized.

6. A DNA sequence is A-A-G-C-T-C. The complementary mRNA sequence is:

   A. T-T-C-G-A-G

   B. U-U-G-C-U-G

   C. U-U-C-G-A-G

   D. T-T-C-G-U-G

## mRNA Processing

Once mRNA has been transcribed, it must exit the nucleus. However, before it can enter the cytoplasm, mRNA must be processed from a primary to a mature molecule.

This consists of removing introns, sections of DNA that are not part of a gene. Exons—the genes (sections of DNA) that will actually code for a protein—are left behind.

Turn to your *Inquiry Into Life* textbook and look at Figure 24.7 on page 241.

There is no assignment for this lesson. Look for the first section assignment after Lesson 2.2.B.

## Summary

**Completing this lesson has helped you to:**

- understand the purpose of transcription and its importance to protein synthesis
- describe the process of transcription from DNA to mRNA

# Lesson 2.2B
# Protein Synthesis, Part 2: Translation

## Overview

You have learned that DNA provides the raw genetic material that will eventually code for a protein, and how DNA produces the three types of RNA (mRNA, tRNA and rRNA) required to carry out its instructions. You also know that during transcription, the DNA double helix partially unravels with the help of an enzyme, enabling the formation of a single strand of messenger RNA or mRNA. Messenger RNA, though it differs in structure from the DNA that created it, still contains the information needed to carry out protein synthesis.

Recall the numerous different types of proteins, including those that provide structural (hair, nails, and muscle), immune, endocrine, and enzyme functions in an organism. These proteins are essential for life. Messenger RNA has an important task to perform—it carries DNA's instructions from the nucleus out into the cytoplasm.

Now you will explore what happens after a mature strand of mRNA leaves the nucleus.

**Translation** occurs in the cytoplasm, where the purpose of DNA is fulfilled by newly created proteins that perform functions vital to the lives of cells and organisms.

### Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod2.html

## Translation—the Plot and the Players

After mRNA is transcribed in the nucleus, it moves into the cytoplasm to direct the formation of a **polypeptide**—a chain of amino acids joined by peptide bonds. A **protein** may be made from one or more polypeptides. While messenger RNA codes for a particular sequence of building blocks called **amino acids**, it also specifies the order in which they must be joined. Only 20 different amino acids exist, but they can be joined in an enormous number of different ways to create many different proteins.

So, translation is the "process by which the sequence of codons in mRNA dictates the sequence of amino acids in a polypeptide". The players in this complex, choreographed production are mRNA, a variety of enzymes, and the two types of RNA we have yet to discuss in detail—transfer RNA (tRNA) and ribosomal RNA (rRNA).

## mRNA

Messenger RNA or mRNA is a long, single strand composed of a large number of nucleotides. Recall that a nucleotide is the building block of both DNA and RNA. It contains a sugar, phosphate group, and one of four nitrogenous or nitrogen-containing bases:

DNA: adenine (A), thymine (T), cytosine (C), guanine (G)

mRNA: uracil (U) replaces thymine (T)

A **codon** is a three-nucleotide unit on the mRNA strand. Different codons specify different amino acids. For example, in the following chart below AAU and AAC both code for the amino acid asparagine.

**Three-letter codons of messenger RNA, and the amino acids specified by the codons**

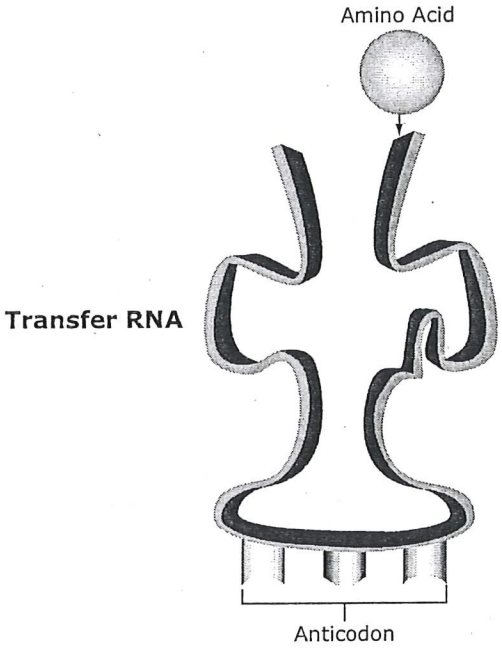
| | | | |
|---|---|---|---|
| AAU, AAC — Asparagine | CAU, CAC — Histidine | GAU, GAC — Asparatic acid | UAU, UAC — Tyrosine |
| AAA, AAG — Lysine | CAA, CAG — Glutamine | GAA, GAG — Glutamic acid | UAA, UAG — Stop |
| ACU, ACC, ACA, ACG — Threonine | CCU, CCC, CCA, CCG — Proline | GCU, GCC, GCA, GCG — Alanine | UCU, UCC, UCA, UCG — Serine |
| AGU, AGC — Serine<br>AGA, AGG — Arginine | CGU, CGC, CGA, CGG — Arginine | GGU, GGC, GGA, GGG — Glycine | UGU, UGC — Cysteine<br>UGA — Stop<br>UGG — Tryptophan |
| AUU, AUC, AUA — Isoleucine<br>AUG — Methionine | CUU, CUC, CUA, CUG — Leucine | GUU, GUC, GUA, GUG — Valine | UUU, UUC — Phenylalanine<br>UUA, UUG — Leucine |

*Codons and the Amino Acids They Specify*

The particular arrangement of codons in mRNA will dictate the way amino acids join together.

## tRNA

Protein synthesis occurs at the **ribosomes** located on rough endoplasmic reticulum. After messenger RNA leaves the nucleus, it will proceed to the ribosomes, but the amino acids that will be joined must also be present. Getting amino acids to the ribosomes is the job of **transfer RNA**. Transfer RNA (tRNA) is a long, single-stranded nucleic acid molecule. In tRNA, complementary base pairing gives the molecule a convoluted, boot-like shape:




The three bases in the tRNA molecule act as an **anticodon** that is complementary to a specific codon of mRNA. Each tRNA molecule also carries one specific amino acid to a ribosome, where protein synthesis is underway.

At the ribosomes, each tRNA anticodon binds to a specific mRNA codon. For example, the tRNA anticodon GCU would bind to the mRNA codon CGA because these bases are complementary. Remember that in RNA, A always pairs with U, and C with G.

## Guided Practice 2.2B 2
# Codon/Anticodon Problem Solving

DNA base sequences, mRNA codons, tRNA anticodons, amino acids...these can get confusing! The following exercise gives practice in determining the relationships between these terms and provides examples of common provincial exam questions.

Fill in the missing spaces to complete the following table (codons, amino acids, and anticodons dictated by a DNA base sequence). The first row is done for you as an example.

| This DNA base sequence... | is transcribed into this mRNA codon... | which codes for this amino acid... | and binds with this tRNA anticodon at a ribosome during protein synthesis. |
|---|---|---|---|
| TTC | AAG | lysine | UUC |
| GAC | CUG | | |
| ACG | | cysteine | |
| ATT | | | |
| | CAU | | GUA |
| | | | CGU |

## One Last Nucleic Acid

There are three types of RNA, and two of those (mRNA and tRNA) have already been discussed. The third type is ribosomal RNA or **rRNA**. It is produced in the **nucleolus**, inside the nucleus, and is a component of ribosomal subunits that come together when protein synthesis begins.

As you will see, ribosomes move along a strand of mRNA. Often, several ribosomes will be translating the same mRNA strand at the same time, but in different locations. They move along like an assembly line. This is called a **polyribosome**, or polysome. Ribosomes exist only until a complete polypeptide chain is formed, then they dissociate into their subunits and fall off the mRNA strand.

If you have access to the Internet, go to the Mader Online Essential Study Partner on the *Biology 12 Web site* Lesson 2.2B Protein Synthesis, Part 2: Translation to view a short animated clip that will help you visualize a polyribosome.

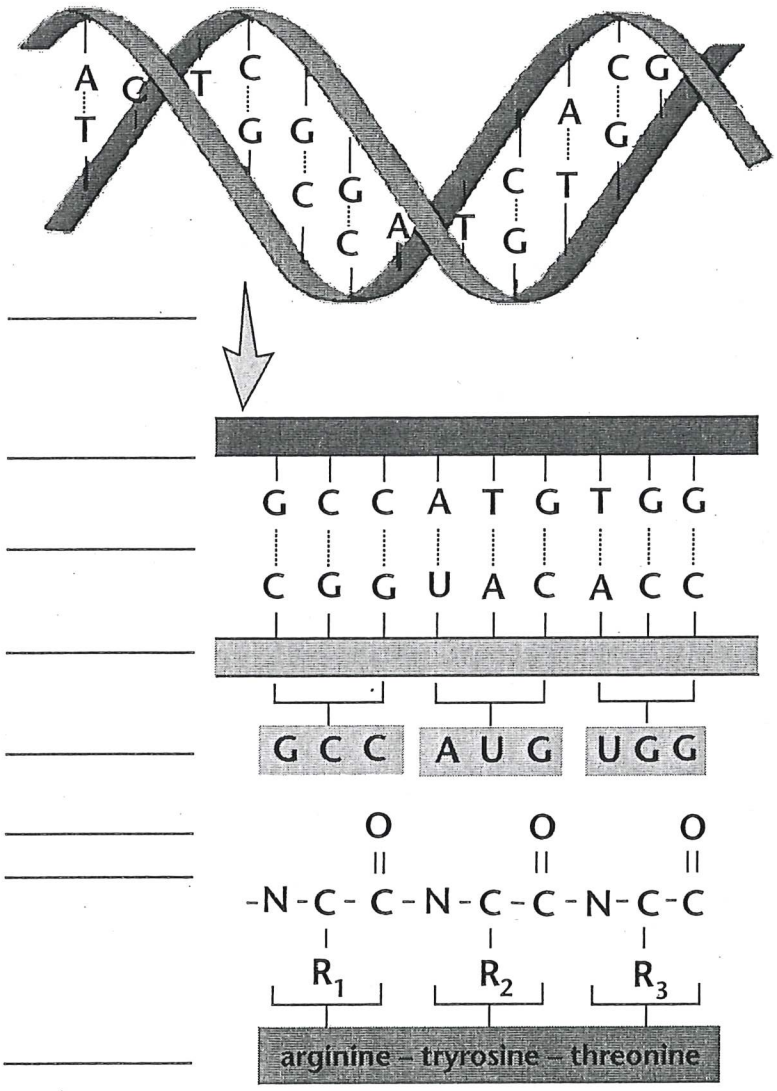
Before you begin the next topic, it's a good idea to review the relationship between the nucleic acids involved in protein synthesis so far. This is the purpose of the next guided practice.

## Guided Practice 2.2B 3
# Putting It All Together

The following provides a quick summary of the processes involved in protein synthesis. Be sure you understand how these steps are related!

Place the eight terms listed into the correct blank box on the diagram provided. Each term identifies a structure or process on the diagram, and each term will be used only once.

List of terms: tRNA anticodons, DNA double helix, amino acids, mRNA codons, DNA, translation, polypeptide, transcription



## Translation: A Production in Three Acts

Begin by reading the section titled "Translation Requires Three Steps" in your *Inquiry Into Life* textbook.

Once you have read about translation, it's time to see this complex process in action. If you have access to the Internet, go to the *Biology 12 Web site* Lesson 2.2B Protein Synthesis, Part 2: Translation and watch the Protein Synthesis animation.

Note that you are not responsible for knowing the names of the 70S ribosome or the P and A sites referred to in the clip. However, do note that two binding sites are available for anticodons carried by tRNA. You may need to replay the clip a few times to get a feel for how mRNA codons and tRNA anticodons interact with ribosomes to link amino acids to a growing polypeptide chain.

You might also choose to visit the Mader Online Essential Study Partner on the *Biology 12 Web site* and review the section titled "Translation." Focus on sections 2.108 through 2.111.

Alternately, to see an animation of translation, go to the *Biology 12 Web site* Lesson 2.2B Protein Synthesis, Part 2: Translation.

As you read about the process of translation, it will be helpful to refer to the "Protein Synthesis" diagram in your *Inquiry Into Life* textbook. This is actually a series of diagrams illustrating the entire mechanism of translation.

Act I of protein synthesis is chain **initiation**, when synthesis begins. On mRNA, the codon AUG codes for methionine, the start codon. The ribosome assembles at the AUG codon along with the first tRNA molecule and its anticodon.

Note that the ribosome, not the mRNA strand, will move during synthesis. Protein synthesis does not begin until a ribosome reaches the start codon (AUG) on the mRNA strand.

Act 2, chain **elongation**, is exactly that. A polypeptide chain grows longer as amino acids are added to it, one at a time. When a new tRNA molecule arrives at the ribosome carrying a second amino acid, it lands on the second of two binding sites on the ribosome. Methionine, the start codon, is still situated on the first binding site.

Next, methionine is peptide-bonded to the amino acid that landed with the new tRNA.

As the ribosome moves along the mRNA strand, one codon at a time (this ribosome movement is called translocation), the tRNA molecule that has delivered its amino acids leaves the ribosome. It will return again and again, each time with another amino acid to be joined to the chain. Over and over, tRNA delivers amino acids that form peptide bonds with the growing polypeptide chain.

Act 3 is chain **termination**. There are three codons that do not specify an amino acid. Instead, these signal stop. When the ribosome reaches a stop codon, an enzyme, also called a release factor, binds to one of the two binding sites and sets the polypeptide chain free from the last tRNA molecule.

After the production is over, the cast (ribosome, tRNA, mRNA) separates. An mRNA strand can be translated again, but it will only last as long as the polypeptide it codes for is needed.

If you have access to the Internet, go to the *Biology 12 Web site* Lesson 2.2B Protein Synthesis, Part 2: Translation and try a quick and easy interactive simulation of protein synthesis. As a review, go to the *Biology 12 Web site* Lesson 2.2B Protein Synthesis, Part 2: Translation and try to create a protein with a given DNA strand to transcribe and translate.

## Guided Practice 2.2B 4
## Connecting the Steps

Now that you have seen what is required to create a polypeptide, check your understanding with the following guided practice.

1. The process of polypeptide synthesis occurs very quickly and seamlessly, but we separate it into steps to make it easier to understand. The following list of steps is out of sequence. In the left column, write the steps in order by matching the step number to the description.

| | Description | Step Number |
|---|---|---|
| | A ribosome reaches UAA, UGA, or UAG on the mRNA strand | 1. |
| | A tRNA anticodon bonds with mRNA codon via complementary base pairing | 2. |
| | tRNA, a ribosome, and a polypeptide leave the mRNA strand | 3. |
| | A peptide bond forms between two amino acids | 4. |
| | A tRNA lands on the second binding site | 5. |
| | A ribosome assembles at AUG on an mRNA strand | 6. |
| | A tRNA leaves the mRNA strand | 7. |
| | A release factor separates a tRNA molecule from the polypeptide chain | 8. |
| | Translocation occurs | 9. |

2. Give the numbers of the steps included in:

   - chain initiation
   - chain elongation
   - chain termination

# Lesson 2.2C
# Mutations of DNA

## Overview

Hollywood's interpretation of mutation and mutants aside, the true definition of **mutation** is a change in the sequence of bases within a gene. As you will see, there are different causes for mutation, just as there are different types of mutation. Since a major function of DNA is to code for the formation of proteins, any **genetic disorder** in DNA can lead to inactive or improperly functioning proteins.

These faulty proteins can have a wide range of effects, including common diseases and disorders such as cystic fibrosis, muscular dystrophy, and sickle cell anemia.

In this lesson you will learn about different causes and types of DNA mutations, and some of the effects mutations can have on polypeptide formation.

Before you begin this lesson, try the DNA...Hollywood Style! quiz to see if you can differentiate between the fact and the fiction about mutations.

### Resource List

- *Inquiry Into Life*
- *Biology 12 Provincial Exam Preparation package*
- *Biology 12 Web site*
  http://www.openschool.bc.ca/courses/biology/bi12/mod2.html
- *Biology 12 Media CD*

## Guided Practice 2.2C 1
## DNA...Hollywood Style!

Answer the following true-or-false questions to see if you can separate real science from Hollywood drama!

1. Scientists have the ability to bring back dinosaurs like in *Jurassic Park*.

   T or F

2. It is possible to produce and inject an antibody to erase the effects of mutations. This one comes from the 2006 movie, *X-men: The Last Stand*.

   T or F

3. The opening line of *X-Men: The Last Stand* is, "Mutation—it is the key to our evolution." Is this statement true or false?

   T or F

## What Causes DNA Mutations?

DNA is an essential molecule, and even small errors can have catastrophic consequences for an organism. Mutations occur randomly, so they cannot easily be predicted. Scientists do know that **mutation rates**—the likelihood of a gene mutation occurring during replication—are increased by **environmental mutagens**. These mutagens can be either physical or chemical.

Radiation, including X-rays, gamma rays, and ultraviolet light, is known to cause mutations. In particular, UV light causes a shape change in DNA that prevents proper replication and transcription.

Some organic chemicals also act as mutagens. Sources of these chemicals include industry, pesticides, air pollution, and cigarette smoke.

## Types of Mutations

There are two main types of DNA mutations—those that change only one base, and those that disrupt an entire polypeptide chain. The severity of a mutation's effect varies with mutation type. Some changes have no effect and others can render a protein unusable. The latter can have serious consequences for an affected organism, as we will discuss shortly.

### Point Mutations

A **point mutation** (also known as a **base substitution**) occurs at only one nucleotide in a DNA sequence. This type of mutation involves substitution of a nucleotide base with another, different base. This error occurs during replication. If the DNA's self-correction mechanism fails to correct the error, it is passed on to mRNA during transcription.

There are three types of point mutations.

#### 1. Silent Mutation

A silent mutation is usually the result of a base substitution at the third location of an mRNA codon. It has no effect on the protein coded for by the mutated DNA. For example:

| Base in a DNA strand: **Normal** | mRNA codon that results: | Codes for the amino acid: | Base in a DNA strand: **With mutation** | mRNA codon that results: | Codes for the amino acid: |
|---|---|---|---|---|---|
| AGT | UCA | Serine | AGA | UCU | Serine |

Because UCA and UCU both code for the amino acid serine, the point mutation in DNA (a substitution of adenine for cytosine) has no effect.

### 2. Missense Mutation

A missense mutation is a point mutation in which the base substitution in DNA changes an mRNA codon so that it codes for a different amino acid. For example:

| Base in a DNA strand: **Normal** | mRNA codon that results: | Codes for the amino acid: | Base in a DNA strand: **With mutation** | mRNA codon that results: | Codes for the amino acid: |
|---|---|---|---|---|---|
| AGT | UCA | Serine | AAT | UUA | Leucine |

### 3. Nonsense Mutation

A nonsense mutation is a base substitution in DNA that changes an mRNA to code for a stop codon. When translation occurs, this misplaced stop codon will cause polypeptide formation to end prematurely. For example:

| Base in a DNA strand: **Normal** | mRNA codon that results: | Codes for the amino acid: | Base in a DNA strand: **With mutation** | mRNA codon that results: | Codes for the amino acid: |
|---|---|---|---|---|---|
| AGT | UCA | Serine | ACT | UGA | STOP |

## Frameshift Mutations

As you have seen, a point mutation can cause mRNA to code for a different amino acid, code for stop, or have no effect at all. Any effect that a point mutation does have is limited to just one codon. However, an entire polypeptide can be affected if a base pair is added to or deleted from DNA. A frameshift mutation changes the composition of all the codons that are "downstream" from the added/deleted base pair.

In the following example, a base pair is added to DNA:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DNA sequence (Complementary base pairs): | T<br>A | G<br>C | G<br>C | A<br>T | C<br>G | A<br>T | T<br>A | C<br>G | A<br>T |
| Corresponding mRNA sequence: | U | G | G | A | C | A | U | C | A |
| Amino acid: | Tryptophan | | | Threonine | | | Serine | | |

Now, if a base pair is added to DNA here:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DNA sequence (Complementary base pairs): | T<br>A | G<br>C | G<br>C | A<br>T | **T**<br>**A** | C<br>G | A<br>T | T<br>A | C<br>G |
| Corresponding mRNA sequence: | U | G | G | A | **U** | C | A | U | C |
| Amino acid: | Tryptophan | | | **Isoleucine** | | | **Isoleucine** | | |

Every codon that is downstream of the added DNA base will now be different.

Using the same original DNA sequence, look at the result of a base pair deletion:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DNA sequence (Complementary base pairs): | T<br>A | G<br>C | G<br>C | **A**<br>**T** | C<br>G | A<br>T | T<br>A | C<br>G | A<br>T |
| Corresponding mRNA sequence: | **U** | **G** | **G** | **A** | **C** | **A** | **U** | **C** | **A** |
| Amino acid: | **Tryptophan** | | | **Threonine** | | | **Serine** | | |
| DNA sequence (Complementary base pairs): | T<br>A | G<br>C | G<br>C | **C**<br>**G** | **A**<br>**T** | **T**<br>**A** | **C**<br>**G** | **A**<br>**T** | |
| Corresponding mRNA sequence: | **U** | **G** | **G** | **C** | **A** | **U** | **C** | **A** | |
| Amino acid: | **Tryptophan** | | | **Histidine** | | | | | |

If you have access to a computer and the *Biology 12 Media CD*, open Gene Sequencing now.

Go to your:

*Biology 12 Media CD* > Module 2> **Gene Sequencing.**

Every codon that is downstream of the added DNA base will be different.

Before you proceed, go to the *Biology 12 Web site* Lesson 2.2C Mutations of DNA and revisit the Mader Online Essential Study Partner. Genetics → DNA → Mutation → Section 2.96 features an animated/narrated clip with examples of point mutations (substitution) and frameshift mutations (insertion and deletion).

## Some Effects of DNA Mutations

We have focused on mutations that occur at the gene level—the changes to a DNA sequence, and the effects of those changes on mRNA and proteins. Note that mutations can also occur when entire sections of a chromosome are deleted, duplicated, inverted, or translocated (moved within a chromosome). These mutations involve larger amounts of genetic material, so they can result in major changes to an organism and, perhaps, even to its offspring.

You'll find more information on chromosome mutations in your *Inquiry Into Life* textbook. Read "Changes in chromosomal Structure" in the chapter titled "Genetic Counseling." For more effects of gene mutations, including sickle-cell anemia, read "Genes and Gene Mutations" in the chapter on DNA biology and technology.

If a mutation occurs in diploid body cells (as opposed to reproductive cells), cancer may result. Cancer occurs when a series of mutations results in uncontrolled, repeated cell division. Read "Characteristics of Cancer Cells" in the *Inquiry Into Life* textbook's section on cancer. Note the features of cancerous cells and familiarize yourself with the diagram titled "Development of Cancer."

Mutations occur randomly, but they also occur constantly. As mutations occur, the principles of natural selection determine which mutations will persist (i.e., they confer some advantage to the organism) and which will die out. In short, mutation leads to variation within a species. Not all mutations are harmful but neither are they all beneficial. The overall effect of a mutation on an organism, and on a population, is dictated by many variables.

## Guided Practice 2.2C 3
# Follow the Mutation

Any change to the sequence of bases in a DNA double helix can result in a mutation. In the following activity, you will follow the transcription and translation of a DNA strand to identify how a mutation in this strand can affect the protein coded for by the DNA.

**Three-letter codons of messenger RNA, and the amino acids specified by the codons**

| | | | |
|---|---|---|---|
| AAU, AAC — Asparagine | CAU, CAC — Histidine | GAU, GAC — Asparatic acid | UAU, UAC — Tyrosine |
| AAA, AAG — Lysine | CAA, CAG — Glutamine | GAA, GAG — Glutamic acid | UAA, UAG — Stop |
| ACU, ACC, ACA, ACG — Threonine | CCU, CCC, CCA, CCG — Proline | GCU, GCC, GCA, GCG — Alanine | UCU, UCC, UCA, UCG — Serine |
| AGU, AGC — Serine<br>AGA, AGG — Arginine | CGU, CGC, CGA, CGG — Arginine | GGU, GGC, GGA, GGG — Glycine | UGU, UGC — Cysteine<br>UGA— Stop<br>UGG— Tryptophan |
| AUU, AUC, AUA — Isoleucine<br>AUG— Methionine | CUU, CUC, CUA, CUG — Leucine | GUU, GUC, GUA, GUG — Valine | UUU, UUC — Phenylalanine<br>UUA, UUG — Leucine |

*Codons and the Amino Acids They Specify*

For each of the following DNA sequences, use the table of Messenger RNA Codons to identify:

- The type of mutation (addition, deletion, substitution)
- how the mutation changes the mRNA sequence that is transcribed
- how the mutation affects the polypeptide chain

Check your answers as you go!

1. DNA sequence:

| A | C | C | T | A | G | A | G | C | T |
|---|---|---|---|---|---|---|---|---|---|

A. What is the mRNA sequence that would be transcribed?

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|

B. Reading from left to right, what three amino acids are coded for by this mRNA sequence?

2. Fill in the boxes to show the effects of the following DNA mutations. Read the DNA strand from left to right. Use the DNA strand provided to answer each question separately. The changes described in part a. do not carry over to part b.

| A | C | C | T | A | G | A | G | C | T |
|---|---|---|---|---|---|---|---|---|---|

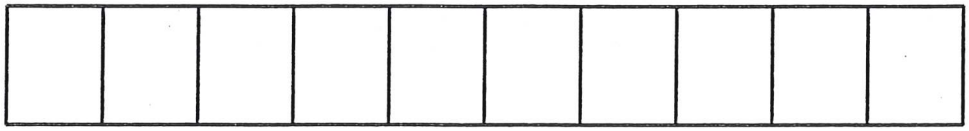
A. A substitution in which T replaces the third base, C:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|

What codons result from this mutation? Enter them here:

| | | | |
|---|---|---|---|

B. A deletion in which the first T is removed from the original DNA strand:



What codons result from this mutation? Enter them here:

C. An addition, add a base A after the first G, using the original DNA strand given:

What codons result from this mutation? Enter them here:

## Summary

**Completing this lesson has helped you to:**

- explain how different types of DNA mutations can affect proteins
- identify the possible effects of substitution, addition, and deletion mutations

Now do Section Assignment 2.2 Parts C and D.