

MAIN Idea

DNA codes for RNA, which guides protein synthesis.

What You'll Learn

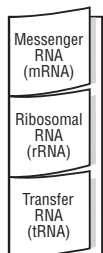
- the different types of RNA involved in transcription and translation
- the role of RNA polymerase in the making of messenger RNA

Study Coach

Create a Quiz Read this section, and create a quiz with answers.

FOLDABLES™

Record Information Make a three-tab Foldable, as shown below, to organize information about the three types of RNA and how each is involved in transcription and translation.



● Before You Read

Computer programmers use a type of language, or code. The computer reads the code and follows the instructions. On the lines below, give other examples of codes. In this section you will learn how DNA, the genetic code, contains instructions for making proteins.

● Read to Learn

Central Dogma

Proteins function as the building blocks of a cell and as enzymes. The instructions for making proteins are found in DNA. The information is read and expressed from DNA to RNA to proteins. This chain of events is called the central dogma of biology: DNA codes for RNA, which guides the making of proteins.

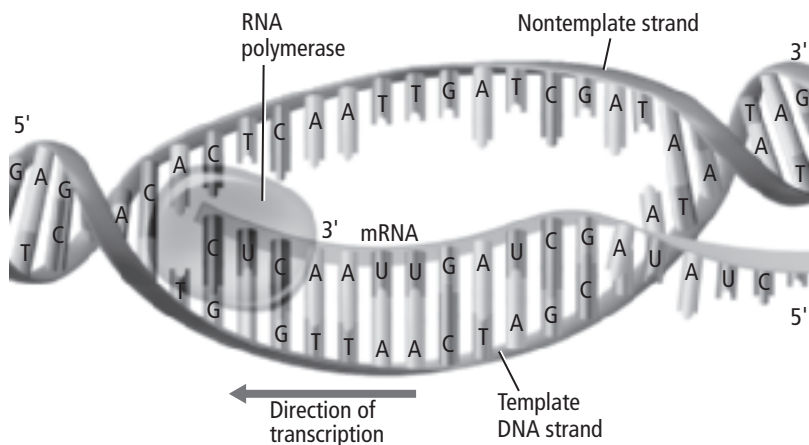
What are the types of RNA?

RNA, like DNA, is a nucleic acid. RNA nucleotides contain the sugar ribose instead of deoxyribose and the base uracil instead of thymine. RNA usually exists in single strands. Cells contain three main types of RNA—messenger RNA, ribosomal RNA, and transfer RNA.

Messenger RNA (mRNA) molecules are long strands of RNA nucleotides that direct ribosomes to make proteins. They travel from the nucleus to the ribosome. Ribosomal RNA (rRNA) molecules make up part of the ribosomes of the cell in the cytoplasm. Transfer RNA (tRNA) molecules transport amino acids from the cytoplasm to the ribosomes.

What happens during transcription?

During **transcription** (trans KRIHP shun), mRNA is made from DNA. As shown below, the DNA is unzipped in the nucleus. **RNA polymerase** binds where mRNA will be made. RNA polymerase makes mRNA in the 5' to 3' direction. Uracil is added to the mRNA strand instead of thymine, making a complement to the DNA strand. The mRNA strand moves out of the nucleus through nuclear pores into the cytoplasm.



How is mRNA processed?

The mRNA code that is made during transcription has all of the DNA code. Before it leaves the nucleus, the pre-mRNA molecule undergoes processing. First, some of the sequences that interrupt the DNA code, called **introns**, are cut out. The sequences that remain in the mRNA molecule are called **exons**. Exons are the protein-coding sequences. ✓

A protective cap is added to the 5' end of the mRNA strand. A string of adenines, called a poly-A tail, is added to the 3' end.

The Code

The only way DNA varies among organisms is the sequence of bases. There are 20 amino acids that are used to make proteins, so DNA must provide at least 20 codes.

In the 1960s, scientists discovered that the DNA code is a three-base code called a **codon**. Each codon is transcribed into the mRNA code.

The genetic code for all 64 codons is shown in the table at the top of the next page. Three codons—UAA, UAG, and UGA—do not code for an amino acid. They are called stop codons because they stop the transcription process. AUG codes for methionine and is the start codon.

Picture This

1. **Draw** an arrow pointing to the location where the DNA is unzipped and where mRNA is made.

✓ Reading Check

2. **Define** What is the name of the sequences that are removed from mRNA during processing?

Picture This

3. Apply Determine the amino acid chain that would result from the sequence AUG-CCC-GGA-UUA-UAG.

Dictionary of the Genetic Code

First Base	Second Base				Third Base
	U	C	A	G	
U	UUU phenylalanine	UCU serine	UAU tyrosine	UGU cysteine	U
	UUC phenylalanine	UCC serine	UAC tyrosine	UGC cysteine	C
	UUA leucine	UCA serine	UAA stop	UGA stop	A
	UUG leucine	UCG serine	UAG stop	UGG tryptophan	G
C	CUU leucine	CCU proline	CAU histidine	CGU arginine	U
	CUC leucine	CCC proline	CAC histidine	CGC arginine	C
	CUA leucine	CCA proline	CAA glutamine	CGA arginine	A
	CUG leucine	CCG proline	CAG glutamine	CGG arginine	G
A	AUU isoleucine	ACU threonine	AAU asparagine	AGU serine	U
	AUC isoleucine	ACC threonine	AAC asparagine	AGC serine	C
	AUA isoleucine	ACA threonine	AAA lysine	AGA arginine	A
	AUG (start) methionine	ACG threonine	AAG lysine	AGG arginine	G
G	GUU valine	GCU alanine	GAU aspartate	GGU glycine	U
	GUC valine	GCC alanine	GAC aspartate	GGC glycine	C
	GUA valine	GCA alanine	GAA glutamate	GGA glycine	A
	GUG valine	GCG alanine	GAG glutamate	GGG glycine	G

What happens during translation?

After the mRNA is made, it leaves the nucleus and moves to the cytoplasm. There the 5' end of the mRNA connects to a ribosome. The ribosome is where the code is read and translated to make proteins through a process called **translation**.

During translation, tRNA molecules act as interpreters of the mRNA. Each tRNA molecule is folded into a cloverleaf shape. The 3' end attaches to a specific amino acid. At the middle of the folded strand, there is a three-base coding sequence called an anticodon. Each anticodon is complementary to a codon on the mRNA. The anticodon is read 3' to 5'.

What is the role of the ribosome?

You can think of the ribosome as a factory for making proteins. Ribosomes are made of two parts—a large subunit and a small subunit. The subunits are not involved in making protein. The two parts of the ribosome come together and attach to an mRNA molecule to complete the ribosome.

Think it Over

- 4. Name** Where in the cell is the mRNA translated? (Circle your answer.)
- cytoplasm
 - nucleus
 - ribosome

How does translation work?

Transcription takes place in the nucleus. Translation occurs in the cytoplasm. Follow the process of protein production in the picture on the next page.

How is a protein made?

A tRNA molecule with the anticodon CAU carrying a methionine amino acid will move in and bind to the mRNA start codon—AUG—on the 5' end.

A tRNA, that is complementary to the mRNA codon, binds to a groove in the ribosome known as the P site. A second tRNA, that is complementary to the second mRNA codon, moves into a second groove called the A site.

The ribosome bonds the new amino acid in the A site and the amino acid in the P site. As the two amino acids join, the tRNA in the P site is released to the third site, called the E site, where it exits the ribosome. Find these sites in the figure.

The ribosome then moves along the mRNA molecule, so the tRNA in the A site shifts to the P site. A new tRNA then moves into the A site. The process continues, adding and joining amino acids in the sequence determined by the mRNA.

The ribosome continues moving along the mRNA, linking amino acids together, until it reaches a stop codon. The mRNA is released from the last tRNA by proteins called release factors, and the ribosome subunits come apart, ending protein synthesis.

One Gene—One Enzyme

Scientists still needed to learn the relationship between the genes and the proteins for which they coded. In the 1940s, George Beadle and Edward Tatum conducted experiments on the mold *Neurospora*. The mold spores they studied were mutated by exposure to X rays. Their experiments showed that a gene can code for an enzyme. Based on the results of their experiments, Beadle and Tatum proposed that each gene makes one enzyme, the “one gene—one enzyme” hypothesis.

How has the one gene—one enzyme hypothesis been revised?

Later experiments by other scientists showed that some enzymes contain more than one polypeptide chain. As a result, the hypothesis has been changed to state that each gene codes for one polypeptide.



Think it Over

5. Identify In what order does a tRNA move through the binding sites on a ribosome? (Circle your answer.)

- a. E site–P site–A site
- b. A site–E site–P site
- c. P site–A site–E site

How does translation make a protein polypeptide?

Picture This

6. Identify Circle the tRNA in the P site.

Follow along with the picture below. You will see how the ribosome translates the mRNA code into a chain of amino acids, called a polypeptide.

