

# Chapter 17

## Gene Expression

### 17.1. Central Dogma of Molecular Biology

Protein synthesis requires two steps: *transcription* and *translation*.

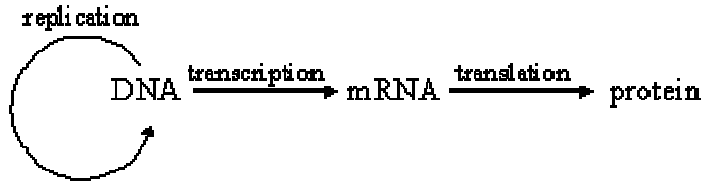


Fig.17.1. Central Dogma of Molecular Biology

### 17.2. DNA Contains Codes

Three bases in DNA code for one amino acid. The DNA code is copied to produce mRNA. The order of amino acids in the polypeptide is determined by the sequence of 3-letter codes in mRNA.

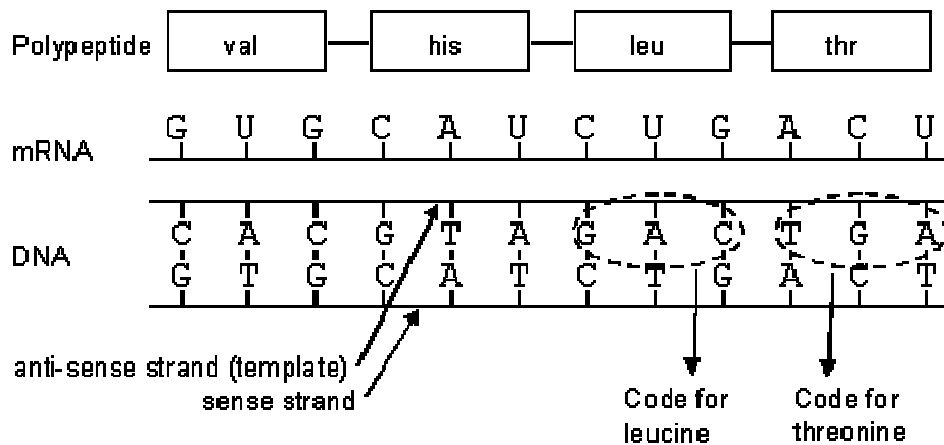


Fig.17.2. Gene Segment

### 17.3. Kinds of RNA

#### (a) Messenger RNA (mRNA)

Messenger RNA contains genetic information. It is a copy of a portion of the DNA. It carries genetic information from the gene (DNA) out of the nucleus, into the cytoplasm of the cell where it is translated to produce protein.

#### (b) Ribosomal RNA (rRNA)

This type of RNA is a structural component of the ribosomes. It does not contain a genetic message.

#### (c) Transfer RNA (tRNA)

Transfer RNA functions to transport amino acids to the ribosomes during protein synthesis.

## 17.4. Transcription

**Transcription** is the synthesis of mRNA from a DNA template. It is like DNA replication in that a DNA strand is used to synthesize a strand of mRNA. Only one strand of DNA is copied. A single gene may be transcribed thousands of times. After transcription, the DNA strands rejoin.

### (a) Steps Involved in Transcription

DNA unwinds. **RNA polymerase** recognizes a specific base sequence in the DNA called a **promoter** and binds to it. The promoter identifies the start of a gene, which strand is to be copied, and the direction that it is to be copied. Complementary bases are assembled (U instead of T). A **termination code** in the DNA indicates where transcription will stop. The mRNA produced is called a **mRNA transcript**.

### (b) Processing the mRNA Transcript

In eukaryotic cells, the newly-formed mRNA transcript (also called heterogenous nuclear RNA or hnRNA) must be further modified before it can be used. A cap is added to the 5' end and a poly-A tail (150 to 200 Adenines) is added to the 3' end of the molecule. The newly-formed mRNA has regions that do not contain a genetic message. These regions are called **introns** and must be removed. Their function is unknown. The remaining portions of mRNA are called **exons**. They are spliced together to form a **mature mRNA transcript**.

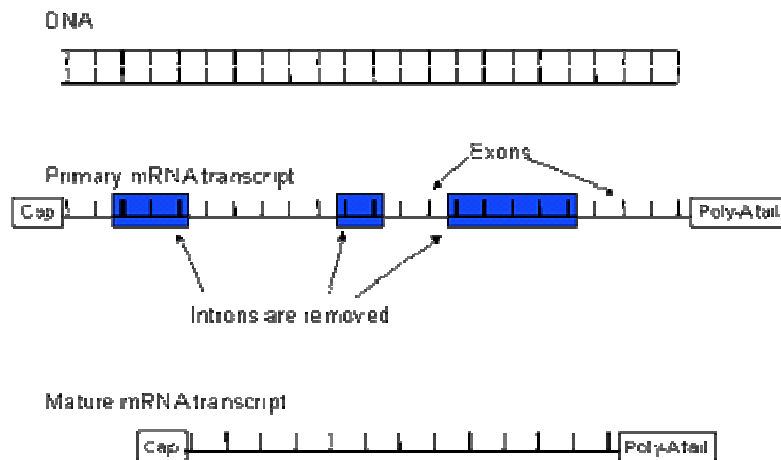


Fig.17.3. Processing the mRNA Transcript

### (c) The Nucleus

DNA is located in the **nucleus**. Transcription and mRNA processing occur in the nucleus. The nucleus is surrounded by a double membrane. After the mature mRNA transcript is produced, it moves out of the nucleus and into the **cytoplasm** through **pores** in the **nuclear membrane**.

## 17.5. Translation

Translation is the process where ribosomes synthesize proteins using the mature mRNA transcript produced during **transcription**. A mature mRNA transcript, a ribosome, several tRNA molecules and amino acids are shown. There is a specific tRNA for each of

the 20 different amino acids. A ribosome attaches to the mRNA transcript. A tRNA molecule transports an amino acid to the ribosome. Notice that the 3-letter *anticodon* on the tRNA molecule matches the 3-letter code (called a *codon*) in the mRNA. The tRNA with the anticodon "UAC" bonds with methionine. It always transports methionine. Transfer RNA molecules with different anticodons transport other amino acids. A second tRNA molecule bonds to the mRNA at the ribosome. Again, the codes must match. A bond is formed between the two amino acids. The tRNA bonded to methionine drops off and can be reused later. The ribosome moves along the mRNA to expose another codon (GAU) for a tRNA molecule. The only tRNA molecule that can bond to the GAU site is a molecule with a CUA anticodon. Transfer RNA molecules with CUA anticodons are specific for asparagine. Asparagine is now added to the growing amino acid chain.

### (a) Initiation and Termination Codes

An *initiation code* signals the start of a genetic message. As the ribosome moves along a mRNA transcript, it will not begin synthesizing protein until it reaches an initiation code. *Termination codes* signal the end of the genetic message. Synthesis stops when the ribosome reaches a terminator codon.

### (b) Genetic Code

The table below can be used to determine what amino acid corresponds to any 3-letter codon.

		Second letter				
		U	C	A	G	
U	UUU } Phe	UCU } Ser	UAU } Tyr	UGU } Cys	U	
	UUC } Phe	UCC } Ser	UAC } Tyr	UGC } Cys	C	
	UUA } Leu	UCA } Ser	UAA Stop	UGA Stop	A	
	UUG } Leu	UCG } Ser	UAG Stop	UGG Trp	G	
C	CUU } Leu	CCU } Pro	CAU } His	CGU } Arg	U	
	CUC } Leu	CCC } Pro	CAC } His	CGC } Arg	C	
	CUA } Leu	CCA } Pro	CAA } Gln	CGA } Arg	A	
	CUG } Leu	CCG } Pro	CAG } Gln	CGG } Arg	G	
A	AUU } Ile	ACU } Thr	AAU } Asn	AGU } Ser	U	
	AUC } Ile	ACC } Thr	AAC } Asn	AGC } Ser	C	
	AUA } Ile	ACA } Thr	AAA } Lys	AGA } Arg	A	
	AUG Met	ACG } Thr	AAG } Lys	AGG } Arg	G	
G	GUU } Val	GCU } Ala	GAU } Asp	GGU } Gly	U	
	GUC } Val	GCC } Ala	GAC } Asp	GGC } Gly	C	
	GUA } Val	GCA } Ala	GAA } Glu	GGA } Gly	A	
	GUG } Val	GCG } Ala	GAG } Glu	GGG } Gly	G	

Fig.17.3. Genetic Code

## 17.6. Mutation

Mutations are changes in the DNA.

### (A) Frameshift

A frameshift mutation is usually severe, producing a completely nonfunctional protein. The principle of a frameshift can be explained using the sentence below. If the letters are read three at a time and one is deleted, the second sentence becomes meaningless.

## **(B) Point Mutation**

Point mutations involve a single nucleotide, thus a single amino acid. In the sentence below, eliminating one letter does not change in the remaining three-letter words and therefore may not cause a significant change in the meaning of the sentence.

## **(C) Silent, Mis-sense, and Nonsense Mutations**

Three kinds of point mutations can occur. A mutation that results in an amino acid substitution is called a mis-sense mutation. A mutation that results in a stop codon so that incomplete proteins are produced, it is called a nonsense mutation. A mutation that produces a functioning protein is called a silent mutation.