RNA Synthesis and Splicing

RNA (ribonucleic acid) is made up of nucleotides containing the sugar ribose. This sugar accounts for the scientific name of this polynucleotide. The four nucleotides that make up the RNA molecule have the following bases: **Adenine (A), Uracil (U), Cytosine (C), and Guanine (G).**

RNA can be divided into **coding and non-coding RNAs.** The coding RNA is a messenger RNA (**mRNA**), which is translated into protein, while the non-coding RNA is divided into ribosomal RNA (rRNA), transfer RNA (tRNA), and the small RNAs (**sRNA**). The small RNAs are involved in the expression of the genes that code for mRNA and rRNA.

Table 1: DNA–RNA Similarities and Differences:

DNA–RNA Similarities	
Nucleic acids Composed of nucleotides Sugar–phosphate backbone Four different types of bases	
DNA–RNA Differences	
DNA	***RNA***
Found in nucleus and ***mitochondria***	Found in nucleus and cytoplasm
The genetic material	Helper to DNA but it is the genetic material of some viruses.
The pentose sugar is deoxyribose	The pentose sugar is ribose
Bases are A, T, C, G	Bases are A, U, C, G
Double-stranded	Single-stranded
Is transcribed (to give RNA)	Can be translated (to give proteins)
double-helix	Single strand
DNA is only of one type	There are three types of RNA messenger, ribosomal and transfer RNA.

There are three major types of RNA. Each has specific functions in protein synthesis:

1. ***Messenger RNA***: It is produced in the nucleus where DNA serves as a template for its formation. This type of RNA carries genetic information for protein synthesis from DNA to the ribosomes in the cytoplasm, where protein synthesis occurs. It consists of only 3 to 5% of the total cellular RNA.

2. ***Ribosomal RNA***: (rRNA): along with protein, makes up the ribosomes. Where proteins are synthesized. It is found in the ribosomes. It comprises about 80% of the total RNA of the cell. The base sequence of rRNA is complementary to that of the region of DNA where it is synthesized.
3. ***Transfer RNA*** (tRNA): It plays a role to transfer amino acid to ribosomes. It is also called soluble RNA because it is too small to be precipitated by ultracentrifugation at 100,000.

Structure and Function of Proteins:

Proteins are composed of subunits called amino acids. Twenty different amino acids are commonly found in proteins. Proteins are widely used in cells to serve diverse functions. Some of them provide the structural support for cells while others act as enzymes to catalyze certain reactions. Proteins differ because of the number and order of their amino acids. The sequence of amino acids in protein leads to its particular shape.

Protein synthesis begins in the cell's nucleus when the gene encoding a protein is copied into RNA. The process of transferring the gene's DNA into RNA is called transcription. Transcription helps to magnify the amount of DNA by creating many copies of RNA that can act as the template for protein synthesis. The RNA copy of the gene is called the mRNA. The gene expression has two major steps including transcription and translation.

Gene Expression:

At the molecular level, gene represents a **transcriptional unite**. it can be transcribed into RNA. Several different types of base sequences perform different roles during of gene expression, for example, the promoter and terminator are nucleotide base sequences which are used in transcription.

In DNA:

Promoter: is a regulatory region of DNA where transcription of a gene is initiated. It represents an RNA polymerase binding site for signals the beginning of transcription.

Terminator: it is a section of nucleic acid sequence that marks the end of genetic transcription.

Regulatory sequences: site for the binding the regulatory protein.

In mRNA:

Ribosomal – binding site: site for ribosome binding, translation begins near this site in the mRNA.

Start codon: Specifies the first amino acid in protein sequences. (AUG).

Codon: a three nucleotides sequence within mRNA that specifies a particular amino acid.

Transcription:

The biosynthesis of RNA, called transcription, proceeds in much the same fashion as the replication of DNA and also follows the base pairing principle. During transcription, a section of DNA double helix is uncoiled and only one of the DNA strands serves as a template for RNA polymerase enzyme to guide the synthesis of RNA. After the synthesis is complete, the RNA separates from the DNA and the DNA recoils into its helix.

The RNA transcription process occurs in three stages: initiation, chain elongation, and termination.

1. **Initiation**:

The first stage occurs when the RNA Polymerase-Promoter Complex binds to the promoter region which functions as a recognition site for transcription factors in the DNA. This also allows for the finding of the start sequence for the RNA polymerase. The promoter enzyme will not work unless the sigma protein is present. The transcription factors enable RNA polymerase to bind to the promoter region of DNA. Following binding, the DNA is denatured into a bubble known as the open complex.

2. **Elongation:**

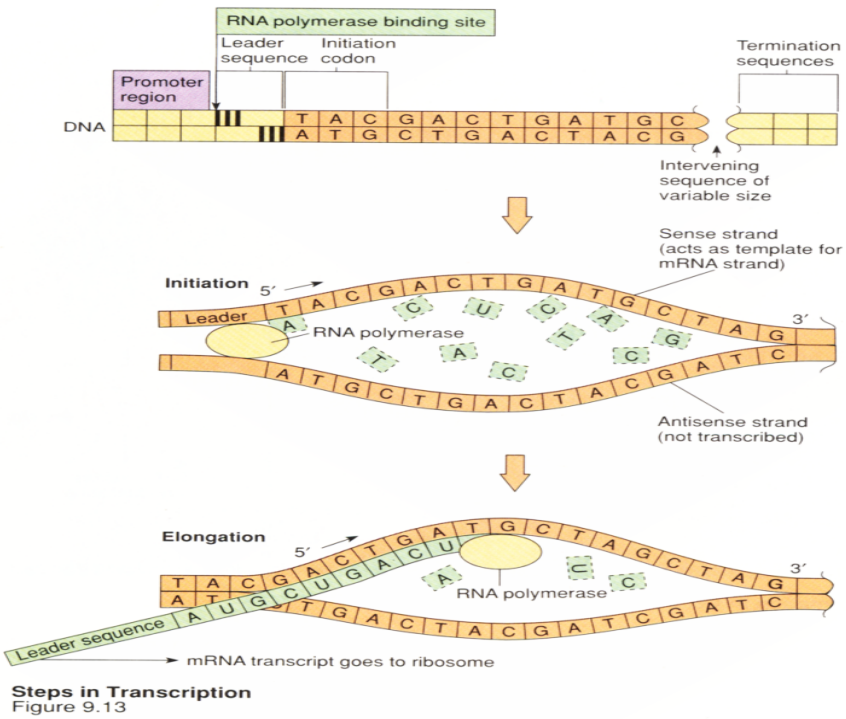
The elongation begins when the RNA polymerase "reads" the template DNA. Only one strand of the DNA is read for the base sequence. The RNA is synthesized is the complementary strand of the DNA.

3. **Termination:** A termination signal is reached that causes RNA polymerase the RNA transcript to dissociate the DNA.

Transcription can be summarized as follows:

1. It takes place in the nucleus of eukaryotic cells.
2. It is the first step in gene expression leading to protein synthesis
3. The process involved unwinding of DNA segments.
4. Complementary RNA nucleotides pair with DNA nucleotides of the strand to be transcribed.

5. RNA polymerase is needed for joining together RNA nucleotides.
6. DNA acts as a template for RNA.
7. The start of a gene in the direction of transcription is called a promoter.
8. mRNA formed directs protein synthesis.
9. mRNA strand is shorter than DNA because only certain segments or portions of DNA (exons) would be bind to m RNA.
10. An enzyme spliceosome is required for cutting the primary mRNA.
11. It is possible that the introns allow crossing over within a gene during meiosis



Steps in Transcription
Figure 9.13

Processing mRNA:

Before the transcribed mRNA leaves the nucleus for translation in the cytoplasm, it undergoes a series of processing steps. The newly synthesized primary mRNA molecule becomes **a mature mRNA molecule** after processing. Most genes in humans are interrupted by segments of DNA that are not part of the gene. These portions are **called introns** because they are intra-gene segments and do not code for a functional protein. The other portions of the gene are called exons because they are ultimately expressed. Only exons result in a protein product.

Primary mRNA contains bases complementary to both exons and introns, but during processing (1) one end of the mRNA is capped by the addition of an altered guanine nucleotide. The other end is given a tail, by the addition of multiple adenosine nucleotides. **(**2) The introns are removed, and the exons are joined to form

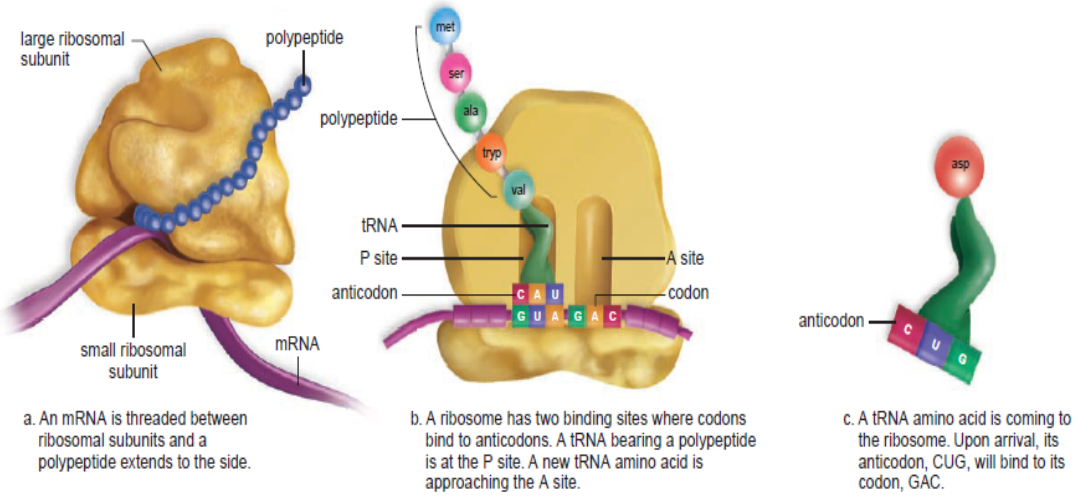
a mature mRNA molecule consisting of continuous exons. This splicing of mRNA is done by a complex composed of both RNA (a small RNA molecule) and protein.

Translation

The next stage, which occurs in the cytoplasm is called Translation in which each mRNA molecule becomes attached to one or more ribosomes. the ribosome moves along mRNA from the 5' to the 3' and each codon is recognized by a matching complementary tRNA which contributes its amino acid to the end a new growing protein chain until a stop codon is reached. There are three steps:

1. **Initiation of translation:** small ribosome subunit attaches to the mRNA in the vicinity **of the start codon (AUG)**, then a large ribosomal subunit joins to small subunit. translation begins.
2. **Chain elongation:** Each ribosome contain two site the P (for polypeptides site) and A (for amino acid site)

   At the start of elongation: A tRNA with an attached polypeptide is at the P site and A tRNA amino acid complex at A site. Then translocation occurs: the mRNA. along with peptide bearing tRNA, move from the A site to empty P site
3. **Chain termination:** termination of polypeptides synthesis occur at a stop codon, which does not code for amino acid, the polypeptide is enzymatically cleaved from the last tRNA, the tRNA and polypeptide leave the ribosome**.**



a. An mRNA is threaded between ribosomal subunits and a polypeptide extends to the side.

b. A ribosome has two binding sites where codons bind to anticodons. A tRNA bearing a polypeptide is at the P site. A new tRNA amino acid is approaching the A site.

c. A tRNA amino acid is coming to the ribosome. Upon arrival, its anticodon, CUG, will bind to its codon, GAC.

Figure 1: The roles of all three forms of RNA in translation.

Translation can be summarized as follow:

1. Takes place in the cytoplasm of eukaryotic cells.
2. Translation is considered as a second step in gene expression leading to protein synthesis,
3. rRNA+protein =ribosomes in the cytoplasm either free or bound to the surface of endoplasmic reticulum.
4. Ribosomes consists of two subunits: the large subunit consists of two RNA molecules plus protein whereas the small subunit consists of one RNA molecules plus proteins.
5. mRNA is translated by one ribosome which is specific for one amino acid.
6. tRNA transfer one amino acid to ribosomes.
7. Complementary base pairing between m RNA (codon) and tRNA (anticodon) occur.
8. The result is gene expression that leads to protein synthesis.

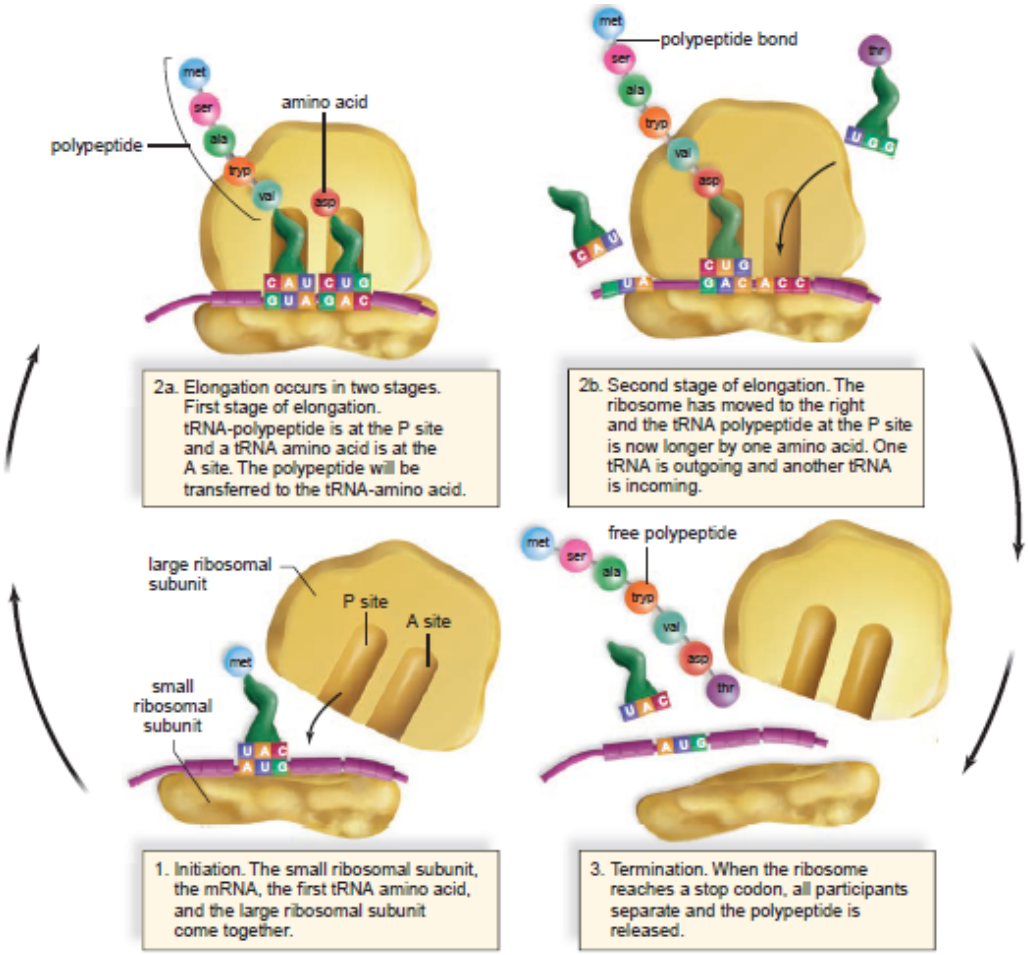


Figure 2: Formation of the polypeptide during translation